SURVEY OF INDIA

TECHNICAL REPORT

1951

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INTRODUCTION

This report gives a detailed account of the activities of the Geodetic and Training Circle during the period 1st April 1950 to 31st March 1951. The following is a brief review of the contents.

2. *Triangulation and Base Measurement.*—(Chapter I). Two important primary triangulation series were executed during the period. One was a portion of the older Calcutta Meridional Series, observed to serve as a basis for the demarcation of the East-West Bengal boundary. It lay through flat and featureless country necessitating the use of Bilby towers to ensure intervisibility of the stations.

The second series was run in the Andamans to provide framework control for the large scale mapping. Before the war, Port Blair in the Andaman Islands used to be a Penal settlement, but now the government is planning to develop it for resettling the refugees from Pākistān. Large scale maps have consequently become an urgent necessity. These islands were surveyed topographically by the Survey of India in 1883–86, but the methods used were rather crude and the lay-out of the triangulation was poor. A precise astronomical fixing of datum has been made and has revealed that the Andaman Islands were out of position on the existing maps by about two-thirds of a mile.

The reconnaissance and triangulation of the Andaman group including the outlying islands presented a formidable problem. The inland hills are extremely difficult of approach being covered with dense tropical forests, the trees being over-laden with climbers. Labour for jungle clearing is sparse, transport scarce and ocean going vessels which are needed for approaching some outlying islands are hardly available. Part of the triangulation lies through the territory of the Jarawas—an entirely hostile tribe, adept at ambushing and apt to kill every stranger at sight.

Precision traverses and levelling were carried out in Car Nicobar Islands to provide framework data for the air survey of these islands.

3. *Observatories.*—(Chapter II). Observations for horizontal force and declination were made at 13 stations in South India. A revised isogonal chart for this area has been prepared.

The 24-metre invar wires used for geodetic base measurement were standardized before and after the field season at Dehra Dūn.

4. *Levelling.*—(Chapter III). During the period under report, 141 miles of levelling of high precision was carried out in one direction and 436 miles in both directions. A circuit of about 140 miles

of tertiary levelling was run in Car Nicobar Islands and 822 miles of secondary levelling was carried out in Rājasthān and for the Bhakra Dam Project.

The heights above mean sea-level of the zeroes of four water gauges erected at the river Padma (Ganges) were also determined for the Indian and Pākistāni Hydrographical survey parties.

5. *Tides.*—(Chapter IV). A standard automatic tide-gauge of U.S.A. pattern was installed at Kandla port in 1950 and has since been in operation. A site has been selected for the proposed new tidal observatory at Port Blair.

Half-hourly observations for a period of 31 days were carried out on tide-poles at three ports—Port Albert Victor, Navabandar and Bhavnagar. The results have been analysed and tidal constants derived.

6. *Gravity.*—(Chapter VI). Gravity was observed at 47 stations in P.E.P.S.U. and the Punjab. In addition, a gravimeter traverse was run between Lucknow and Delhi.

Observations with the Worden gravimeter were made at Calcutta, Dehra Dūn, Mussoorie, Chakrāta and Srinagar.

DEHRA DŪN:
March 1952.

B. L. GULATEE, M.A. (CANTAB.),
F.R.I.C.S., M.I.S. (INDIA),
Director, Geodetic and Training Circle,
Survey of India, Dehra Dūn.

PERSONNEL OF THE GEODETIC AND TRAINING CIRCLE

Director, Geodetic and Training Circle

SHRI B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA).

Dy. Director, Geodetic and Training Circle

SHRI P. A. THOMAS, M.I.S. (INDIA), OFFICIATING

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Shri Balwant Singh (Offg.).

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President, Geodetic and Research Branch

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1 Driver.

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1 Air Survey Draftsman.

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Shri C. S. Pramar do.

Shri Anant Singh do.

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Primary and Secondary Triangulation Series

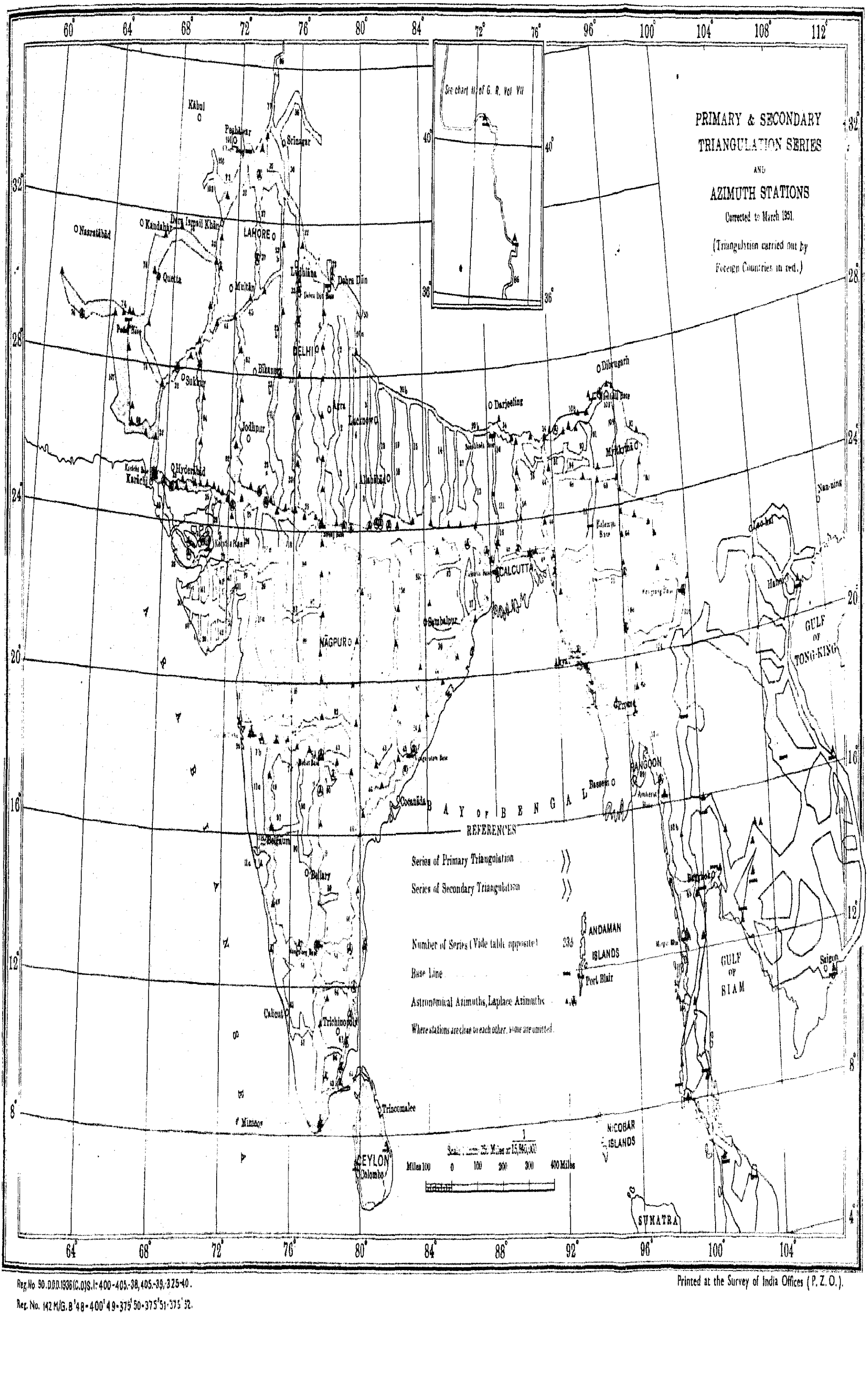
No.	Name of Series	Season	± m	± p	Instrument
	Primary Series		"	ft.	inches
5	Calcutta Longitudinal	1864–69	0.369	2.23	36 & 24
6	Great Arc Meridional, Section 24°–30° ..	1835–66	0.708	4.26	36
7a	Bombay Longitudinal, East of 75° ..	1862–63	0.762	2.13	24
8	Great Arc Meridional, Section 18°–24° ..	1837–41	0.567	1.26	36
9	Great Arc Meridional, Section 8°–18° ..	1866–74	0.390	1.80	24
11b	South Konkan Coast ..	1866–67	0.392	0.77	24
20a	North-East Longitudinal, West of 80° ..	1850–51	0.558	1.05	24
22	North West Himālaya	1848–53	0.641	2.15	24
23b	Gurhāgarh Meridional between $26\frac{1}{4}$°–$32\frac{1}{4}$° ..	1859–62	0.362	0.96	24
24	East Coast ..	1848–63	0.608	1.58	24
25	Karāchi Longitudinal	1849–55	0.558	1.88	36
32	Great Indus ..	1853–61	0.359	1.74	36 & 24
33	Rahūn Meridional ..	1853–63	0.327	1.24	24
34	Assam Longitudinal	1854–60	0.579	1.52	24
37	Jogi-Tila Meridional ..	1855–62	0.481	1.67	36 & 24
43	Bidar Longitudinal ..	1860–72	0.311	1.21	36 & 24
44	Eastern Frontier or Shillong Meridional ..	1860–64	0.409	1.24	24
45	Sutlej ..	1861–63	0.346	1.74	36
46	Madras Meridional and Coast ..	1860–68	0.426	1.28	36 & 24
49	Mangalore Meridional	1863–73	0.440	1.14	24
52a	Burma Coast (See 106)	1864–82	0.386	1.21	24
53	Jubbulpore Meridional	1864–67	0.340	1.04	36
54	Madras Longitudinal .	1865–73	0.384	1.23	24
56	Brahmaputra Meridional ..	1868–74	0.564	1.02	24
58	Bilāspur Meridional ..	1869–73	0.302	0.98	36 & 24
62	Jodhpur Meridional ..	1873–76	0.291	1.11	24
63	South-East Coast ..	1874–80	0.522	1.33	24
64	Eastern Sind Meridional ..	1876–81	0.244	1.25	24
66	Mandalay Meridional (See 109)	1889–95	0.418	1.46	12
68	Manipur Longitudinal	1894–99	0.453	1.45	12
69	Makrān Longitudinal ..	1895–97	0:285	0.92	12
72	Great Salween (See 105)	1900–11	0.404	4.28	12
74	Kalāt Longitudinal ..	1904–08	0.365	3.15	12
76	North Baluchistān ..	1908–10	0.221	1.82	12
77	Gilgit ..	1909–11	0.443	2.62	12
80	Upper Irrawaddy ..	1909–11	0.596	3.14	12
85	Sambalpur Meridional	1911–14	0.250	1.28	12
103	Chittagong ..	1928–30	0.453	2.181	$5\frac{1}{2}$
104	Mong Hsat ..	1929–31	0.441	1.67	12 & $5\frac{1}{2}$ Wild
105	Great Salween ..	1929–31	0.682	3.04	12 & $5\frac{1}{2}$ Wild
106	Burma Coast ..	1930–31	0.205	1.29	12
107	Dālbandin ..	1931–32	0.472	4.55	$5\frac{1}{2}$ Wild
108	Assam Longitudinal ..	1934–36	0.426	1.034	$5\frac{1}{2}$ Wild
109	Mandalay Meridional ..	1936–37	0.422	2.900	$5\frac{1}{2}$ Wild
110	Kandla* ..	1949–50	0·538	1.94	Geodetic Tavistock
111	East-West Bengal boundary	1950–51	0·456	0·896	Geodetic Tavistock
	Secondary Series				
1	South Pārasnāth Meridional ..	1836–39	3.308	9.98	18
2	Budhon Meridional ..	1833–43	2.242	7.47	18 & 15
3	Amūa Meridional ..	1834–38	1.647	4.71	18
4	Rangir Meridional ..	1834–41	1.643	7.52	18 & 15
7b	Bombay Longitudinal West of 75° ..	1837–39	0.919	2.24	15
10a	Singi Meridional 21°–25°	1860–62	0.723	1.19	18
10b	Singi Meridional 19°–21°	1842–46	1.711	1.39	15
11a	South Konkan Coast $15\frac{1}{4}$°–19° ..	1842–44	2.425	1.71	15
12	Karāra Meridional ..	1843–45	1.507	3.46	18 & 15
13	North Malūncha Meridional ..	1844–46	1.266	3.69	18 & 15
14	Chendwār Meridional ..	1844–46	0.841	1.51	36, 24 & 18
15	Gora Meridional ..	1845–47	0.973	3.09	15
16	Calcutta Meridional ..	1845–48	1.173	1.52	18
17	South Maluncha Meridional ..	1845–53	1.606	1.49	24 & 18
18	Khānpisura Meridional	1845–48	1.227	2.11	24 & 15
	Secondary Series—*Contd.*		"	ft.	inches
19	Gurwani Meridional ..	1846–47	1.165	2.57	24 & 18
20b	North-East Longitudinal East of 80° ..	1846–51	0.422	1.41	36, 24 & 15
21	Hurilāong Meridional ..	1848–52	1.502	2.42	24 & 18
23a	Gurhāgarh Meridional $24\frac{1}{2}$°–$26\frac{1}{2}$° ..	1848–50	1.461	2.09	18 & 15
26	Abu Meridional ..	1851–52	0.617	1.53	18
27	North Pārasnāth Meridional ..	1851–52	0.895	2.10	24
28	Kāthiāwār Meridional	1852–56	0.990	2.01	18
29	Gujarāt Longitudinal ..	1852–62	0.859	1.37	18
30	Kāthiāwār Longitudinal ..	1853	1.481	1.66	18
31	Sābarmati ..	1853–54	1.348	0.91	18
35	Cutch Coast ..	1855–58	0.986	1.80	18
36	Kashmīr Principal ..	1855–60	0.884	2.48	14 Vernier
38	Sambalpur Longitudinal ..	1850–57	0.806	1.48	14 Vernier
39	(Cutch) Coast Line ..	1856–60	0.975	1.44	18 & 12
40	Kāthiāwār Meridional No. 1 ..	1858–59	0.930	0.87	18
41	Kāthiāwār Meridional No. 2 ..	1859–60	1.247	1.39	18
42	Kāthiāwār Meridional No. 3 ..	1859–60	0.969	3.36	18
47	Kāthiāwār Meridional No. 4 ..	1863–64	1.154	..	18
48	East Calcutta Longitudinal ..	1863–69	0.379	0.96	24
50	Kumaun and Garhwāl	1864–65	1.742	1.81	14 & 12 Vernier
51	Nāsik ..	1864–65	2.033	0.78	14 & 6
52b	Burma Coast $14\frac{1}{2}$°–16°	1876–77	0.327	1.69	24
57	Coimbatore No. 1 ..	1869–71	1.547	2.50	14
59	Cuddapāh ..	1871–72	0.826	1.32	10
60	Hyderabad ..	1871–72	1.405	0.78	24 & 7
61	Malabar Coast ..	1872–80	1.532	1.17	14 & 12 Vernier
65	Siam Branch ..	1878–81	3.711	2.55	12
67	Mong Hsat ..	1891–93	3.054	2.71	14, 12 & 10
70	Mandalay Longitudinal	1899–1900	1.696	1.00	8
71	Manipur Meridional ..	1899–1902 & 1915–1916	0.750	2.22	12
73	Kidarkanta ..	1902–03	1.323	2.17	12 & 7
75	"Baluchistān" (Bannu)	1908–09	1.348	2.97	12 & 8
78	Khāsi Hills ..	1909–13	2.038	0.76	8
81	Jaintia Hills ..	1910–11	0.986	0.49	8
82	Bhīr ..	1911–12	0.794	2.49	8
83	Rānchi ..	1911–12	1.840	0.61	8
84	Villupuram ..	1911–12	1.184	0.46	8
86	Indo Russian Connection ..	1912–13	2.790	2.17	6
87	Khandwa ..	1912–13	0.999	1.71	8
88	Ashta ..	1913–14	1.048	1.33	8
89	Buldāna ..	1913–14	0.304	0.98	8
90	Naldrug ..	1913–14	1.465	1.91	8
91	Nāga Hills ..	1913–14	0.913	2.17	12
92	Middle Godāvari ..	1914–15	0.913	0.72	8
93	Kohīma ..	1913–15	1.094	1.48	12 & 8
94	Cāchār ..	1914–15	1.077	1.17	12
95	Bombay Island ..	1911–14	..	..	8
96	Madura ..	1916–17	1.148	1.49	8
97	Bāgalkot ..	1916–17	0.701	1.15	8
99	Rangoon ..	1925–27	1.246	..	12
100	Kurram ..	1927–28	2.096	3.80	$3\frac{1}{4}$ Wild
101	Peshāwar ..	1927–28	1.267	5.56	$3\frac{1}{4}$ Wild
102	North Wazīristān ..	1927–28	1.895	2.16	$3\frac{1}{4}$ Wild

± m = root-mean-square error of an unadjusted horizontal angle (in seconds).

± p = root-mean-square error of the unadjusted height difference between two stations (in feet).

*Replaces portions of series 28 and 35.

Chart I



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Chapter I

TRIANGULATION AND BASE MEASUREMENT

BY B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

1. **General.**—Chart I shows in blue the Primary and in green the Secondary Triangulation of India. It is intended ultimately, as finances permit, to strengthen the secondary triangulation and raise its accuracy to that of the primary standard by reobservation and by the insertion of new geodetic bases and Laplace control where necessary. A start was made last year in this direction on the secondary series in the Kutch area.

This programme could not be continued during the year under report, but two new series of Primary triangulation have been observed. One series (about 70 linear miles) was run in connection with the demarcation of East-West Bengal boundary and the other series to provide control for the air survey of Andaman Islands. Owing to the difficulty of terrain and transport, the observations of the geodetic series in the Andaman Islands comprising of 27 stations could not be completed during this field season, about 10 stations still remaining.

A geodetic base, 2·41 miles long was measured in Port Blair.

A crinoline chain traverse has also been run and levelling carried out to provide planimetric and height control for the air survey of the Car Nicobar Islands.

The tidal observatory at Port Blair was closed in 1925. To improve the tidal predictions and to obtain sea-level data for various geodetic and geophysical investigations, it is proposed to re-establish a permanent tidal observatory there.

As the residential portion of Ross Island was completely destroyed by bombing by the Allies during the Japanese occupation in the last war, a site for the tidal observatory has now been selected on the main land on the south side of the Aberdeen jetty.

2. **East-West Bengal Boundary.**—In accordance with an agreement between the Governments of India and Pākistān signed at Delhi on December 14, 1948 an Indo-Pākistān Boundary Disputes Tribunal was set up to settle certain boundary disputes between East and West Bengal and between Assam and East Bengal arising out of the interpretation of the Radcliffe Award of August 1947.

One of the four disputes referred to the Tribunal related to the boundary between the districts of Murshidābād (West Bengal) and Rājshāhi including the *thānas* of Nawābganj and Shibganj of pre-partition Mālda district (East Bengal).

The Calcutta Meridional series of 1845–48 which is the only available triangulation in this area is of secondary quality. On

account of the flatness of the area, the stations consisted of masonry towers about 32 feet high and the sides were about 10 miles long. These towers have all collapsed due to ageing and the inroads of the river on whose banks they are situated. They were, therefore, not available for extension of triangulation or as starting points for traverses to provide control points near the boundary.

Fortunately, some Bilby steel towers had been procured from the American Disposals Stores after the last World War and it was decided at a conference of the survey officers representing both India and Pākistān on July 14, 1950 that a new geodetic series be observed for providing the necessary control for the traverses which were to fix the positions of the boundary pillars. The layout of the new series is shown in Chart II.

3. **Reconnaissance and station building for the new boundary series.**—The boundary survey was undertaken by No. 18 Party of the Survey of India jointly with No. 4 Party of the Survey Department of Pākistān. Mr. L. R. Howard (Surveyor) of No. 18 Party was deputed to inspect and report on the condition of the old stations Jitpur T.S. and Sisa T.S. which were to form the opening side for the new geodetic series. He found the lower mark-stones undisturbed but reported that the towers were completely unusable for observations. Instructions were, therefore, issued that the towers at these stations be dismantled down to ground level, care being taken that the lowest mark was not disturbed in any way.

While Mr. Howard was thus engaged in clearing the sites of these stations, Major S. K. S. Mudaliar, Officer-in-Charge No. 18 Party and Mr. S. Q. Hassan, Officer-in-Charge No. 4 Party (Pākistān) jointly reconnoitred the area for the selection of sites for the new stations. Transport being difficult, an important consideration in the selection of sites was their accessibility by motor transport.

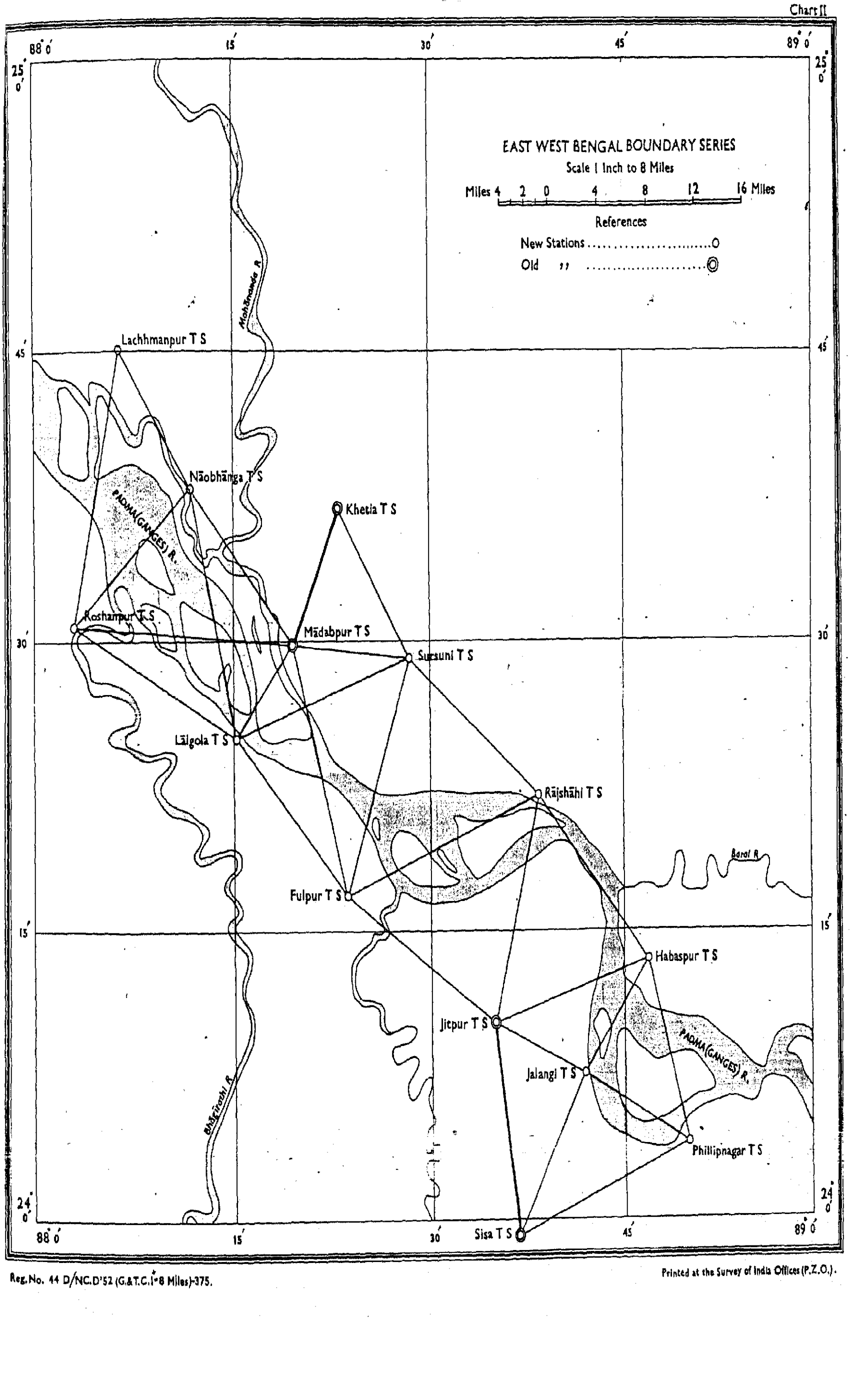
The design of construction of the new stations is shown in Plate III. They consisted of concrete pillars cast in situ with a centrally embedded iron pipe. The pillar consists of a concrete monolith 30 inches square at the base and 6 feet high, the upper 12 inches being a frustum of a pyramid terminating in a square of 8-inch side. The lower four feet of the pillar is embedded in the ground. The total length of the centrally fixed galvanized iron pipe, of 1-inch diameter, is $4\frac{1}{2}$ feet, 6 inches of which projects above the top surface of the monolith.

4. **Erection and dismantling of Bilby towers.**—Observations on Bilby steel towers were taken for the first time in India on this series. These towers can be readily erected and dismantled and transported in a 3-ton truck.

The tower comprises an inner and an outer structure which are mutually independent. The former is meant to support the instrument, the observers with a protecting tent being on the outer structure.

The tower is essentially a combination of the framework of galvanized steel sections and rods of a high degree of rigidity. Its

Chart II

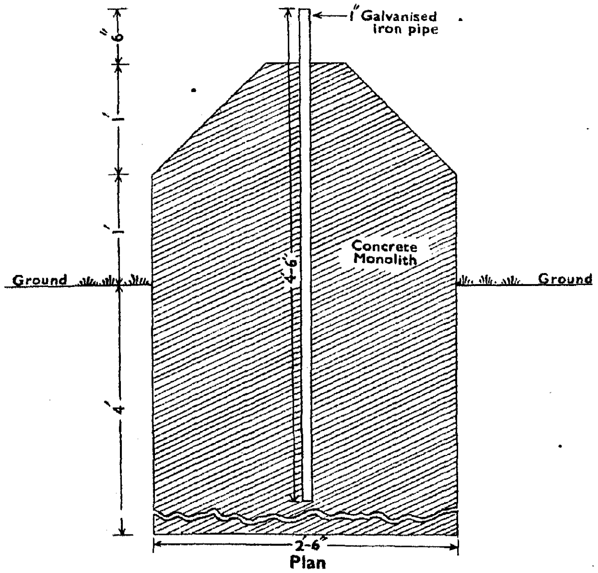


Reg. No. 44 D/NC.D'52 (G.&T.C. 1"=8 Miles)-375.

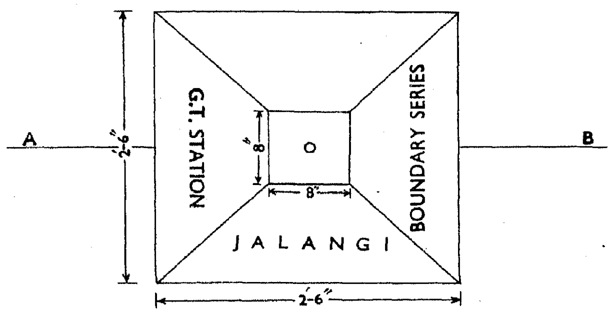
Printed at the Survey of India Offices (P.Z.O.).

THE DESIGN OF CONSTRUCTION OF THE NEW STATIONS

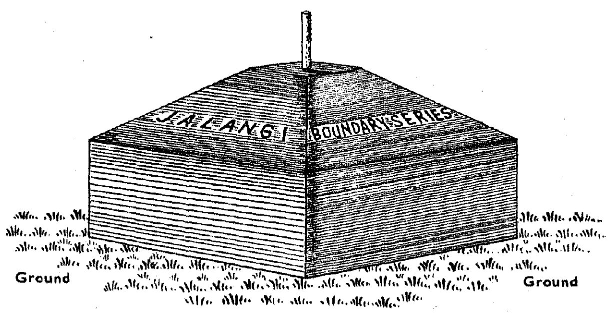
Section on AB



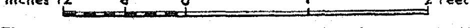
Plan



Isometric view



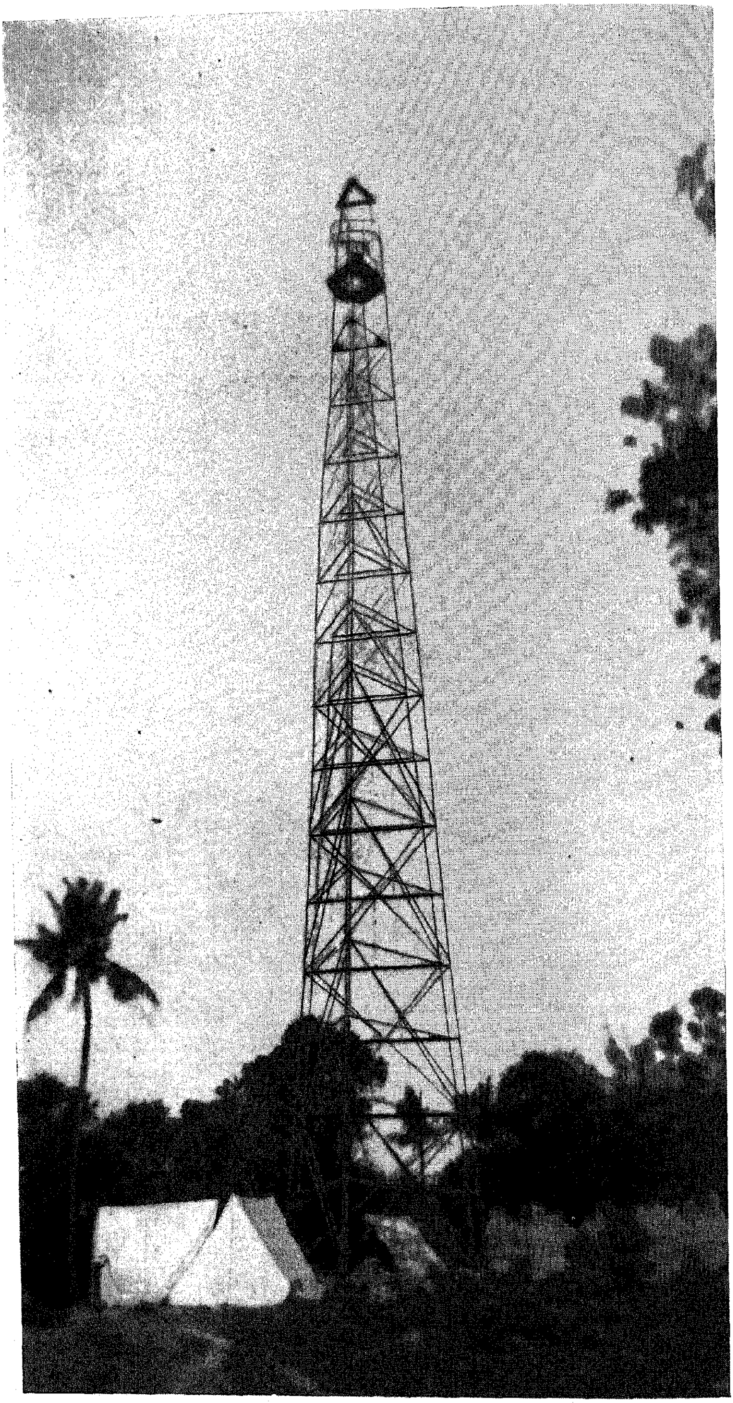
Scale 1 Inch=1·5 Feet



Note:–The station pillar is protected by a 6-foot cairn of earth and rubbles.

Reg. No. 42 D/NC.D'52 (G.&T.C.1"=8 Miles)-375.

Printed at the Survey of India Offices (P.Z.O.).



Bilby Tower erected at Lalgola.

weight is 6640 pounds for a height of 103 feet of the inner structure and 113 feet of the outer structure.

For the East-West Bengal Boundary series, the Bilby towers were erected to the following heights :—

Serial No.	Station	Height of the tower
		feet
1	Sisa T.S.	92·23
2	Jitpur T.S. ..	105·46
3	Jalangi T.S. ..	102·86
4	Phillipnagar T.S. ..	101·88
5	Habaspur T.S. ..	100·97
6	Rājshāhi T.S. ..	102·11
7	Fulpur T.S. ..	88·01
8	Sursuni T.S. ..	101·98
9	Madhabpur T S. ..	108·96
10	Khetia T.S. ..	109·43
11	Lālgola T.S. ..	102·77
12	Roshanpur T.S. ..	103·37
13	Naobhanga T.S. ..	102·16
14	Lachhmanpur T.S. ..	101·94

A picture of the tower erected at Lālgola is given in Plate IV.

For the rapid erection and dismantling of Bilby towers, six teams each consisting of one Class III officer and three *khalāsīs* were specially trained. At each station the team had to employ two local labourers for assistance. Half of the towers were manned by Indian personnel and half by Pākistānīs.

Both the countries agreed that the geodetic triangulation should be executed under the technical guidance of the Director, Geodetic and Training Circle, Dehra Dūn.

5. **Narrative.**—The observation of triangulation was carried out by Messrs. R. S. Chugh, M.A., Deputy Superintending Surveyor (India) and M. Z. Mehdi, B.A., Extra-Assistant Superintendent (Pākistān) each observing half of the number of zeroes at each station. When Mr. Chugh observed Mr. Mehdi acted as the recorder and vice versa. Each of the observers had a squad of seven *khalāsīs* from his own country.

The Bilby towers reached the sites of the stations by 16th November 1950. In India, a Bilby tower with the camp equipment of its team could easily be transported in a 3-ton lorry and a 15-cwt. truck but movement in Pākistān territory was mostly by means of carts and consequently very slow. On an average 8 carts were employed for the transport of each tower. Some use was also made of the Ganges water-way in the area and a large sized boat was engaged at times.

Observations were commenced at Habaspur on 11th December 1950, the work being closed at Lālgola on 28th February 1951.

During this period, the services of Mr. L. R. Howard (India) were put at the disposal of the detachment to assist in administrative arrangements with regard to movement of the towers, obtaining of supplies and rations and centering of the towers on station marks.

Escorts were provided to the observers and Bilby towers erection team in each country. Nothing untoward happened until the close of the field programme when a convoy of bullock carts carrying tower parts under the charge of Mr. T. P. Sinha (India) was attacked by dacoits in Pākistān. There was, however, no loss of life or property and the team crossed safely over the border.

Inter-communication between observers and leaders of Bilby towers erection teams was mostly through couriers.

Supplies were purchased locally in each country. When crossing over from one country to the other not more than one week's rations per head were allowed to be carried. All survey instruments and equipment were passed by the Customs officers without any delay.

All personnel were provided with identity cards or discs which were found to be very useful in travelling in either country. Indian couriers in Pākistān territory travelled with Pākistān Survey employees and vice versa.

The health of the detachment remained good throughout the period.

The towers were found to be quite unsteady in continuous wind or gusts of wind which made the signals appear to jump in all directions rendering their accurate intersection impossible. The observations were also subject to error arising from twist of the tower under lateral heating which was very appreciable from 9:00 hours to 16:00 hours, the diurnal range of temperature being about 25°F. Observations were mostly confined to the intervals from 16:00 hours to sunset and an hour or two at sunrise, during which periods the variation of temperature was only 10°F.

During the month of February there was thick haze in the morning and dust in the evening and the observations were made whenever clear visibility was obtainable. Night observations were not possible except during the month of January due to poor visibility.

6. **Method of Observation.**—Normally 48 measures of each angle were taken, six measures (3 on Face Left and 3 on Face Right) on each of the 8 different zeroes, the zeroes being 0° 01′ 05″, 90° 08′ 55″, 45° 02′ 10″, 135° 07′ 50″, 22° 33′ 20″, 112° 36′ 40″, 67° 34′ 30″ and 157° 35′ 30″. Only two pointings of the micrometer on each reading of a station were made.

Vertical angles were observed between 12 and 15 hours, 2 sets being taken on each face. The heights of stations above ground

level were measured by a calibrated crinoline tape to the nearest tenth of a foot.

7. **Details of the Triangulation.**—The opening side of the series is Sisa T.S.—Jitpur T.S. The accepted values of the log side, bearing and co-ordinates of these stations are given below :—

Log side Sisa T.S.—Jitpur T.S. (in log feet)	= 4·8272973
Latitude of Sisa T.S. ..	= 23° 59′ 06″·901
Longitude of Sisa T.S. ..	= 88 36 31 ·078
Latitude of Jitpur T.S. ..	= 24 10 05 ·742
Longitude of Jitpur T.S. ..	= 88 34 48 ·029
Azimuth at Sisa T.S. of Jitpur T.S.	= 171 46 46 ·62
Azimuth at Jitpur T.S. of Sisa T.S.	= 351 46 04 ...

The series was connected to stations Madhabpur T.S. and Khetia T.S. of the old Calcutta Meridional series. The new and the old values showed the following discrepancies :—

	Old value (1872)	New value (1950)	Discrepancy (Old—New)
	° ′ ″	° ′ ″	″
Latitude of Khetia T.S. ..	24 36 51·254	24 36 51·246	+ 0·008
Longitude of Khetia T.S. ..	88 23 03·194	88 23 03·153	+ 0·041
Azimuth at Khetia T.S. of Madhabpur T.S. ..	24 02 36·50	24 02 29·20	+ 7·30
Log side Khetia T.S.—Madhabpur T.S.	4·6716790	4·6716765	+ 25×10^{-7}

The discrepancies being small, the triangulation was adjusted by semi-rigorous methods. The ground level heights of the opening stations were accepted as follows :—

Height of Sisa T.S. = 56 feet.
Height of Jitpur T.S. = 62 feet.

The heights of the remaining stations were computed from all possible rays. The maximum triangular closure error in height amounted to 4·0 feet.

The average triangular error of the series is 0″·67, and the maximum 1″·47. Average length of the sides of the series is 12·63 miles and the values of m and p are $\pm$0″·456 and $\pm$0·90 feet respectively.

8. **Narrative account of Geodetic work in the Andamans.**—(*a*) *General.*—The geodetic triangulation and base measurement in the Andamans were undertaken to provide a new geodetic framework to serve as basis for the new maps of the islands, which the government have recently ordered to be prepared by air survey. A new astronomical datum at Chatham was also established by observations with a large astrolabe.

The Geodetic Triangulation Detachment consisting of Mr. U. D. Mamgain, Deputy Superintending Surveyor, in charge, Mr. A. K. Bhattacharjee (Officer Surveyor), one Surveyor, two Trig. Computers and 31 *khalāsīs* reached Port Blair via Calcutta on 13th September, 1950. Camp was established on the open ground behind the Central (Cellular) Jail. An empty godown was made available to the Survey Party to accommodate the equipment and stores.

Astronomical observations for latitude and longitude with the large astrolabe were carried out by Mr. J. B. Mathur at the site of the old observatory on Chatham Island towards the end of October. He also observed twin Laplace stations at Mt. Harriett H.S. and Mt. Haughton H.S. and left for India on 1st December 1950. These observations are described in detail in Chapter V.

The officers of the Indian Naval Ship "Kukri" carried out tidal observation at Aberdeen Jetty in Port Blair. The zero of their tide pole was connected to the levelling network which had been carried out by the Levelling Detachment in Port Blair. The navy also carried out simultaneous tidal observations for 15 days in Sisters East and Port Blair.

(*b*) *Reconnaissance and Station Building.*—The reconnaissance for a comprehensive scheme of triangulation covering the entire Andamans and off-lying islands was a very difficult undertaking as there were no roads or paths to the thickly covered hill-tops which in some cases had to be approached by sea. No bullock carts are available and kit had to be transported by labourers, trucks or boats. Some stations in North Andamans required an ocean going boat to get to them which was not available. The detachment had to depend on the transport of the Engineer and Harbour Master and the Forest Department and this sometimes entailed considerable delays as the launches could only be made available when not required by the authorities for their own normal use. The forests contain valuable timber and the transport of the Forest Department is generally fully employed in their exploitation.

Part of the triangulation passes through the territory occupied by the hostile Jarwa tribe. During work in this area, a police guard of one *naik* and 4 constables was provided by the Superintendent of Police for the protection of the survey personnel. A police wireless detachment also accompanied the survey party to maintain contact with Port Blair.

Many sites had to be reconnoitred before a suitable place could be located for the base-line. The country round Port Blair is characterized by a mass of hills enclosing narrow valleys. These are entirely covered by an evergreen dense tropical jungle and there are no stretches of plain ground. A valley west of Tusonābād offered the possibility of a $2\frac{1}{2}$ miles long base and had to be selected although about one mile of the line ran through thick jungle and the rest lay along water-logged rice fields. The actual base measurement had to be deferred till March to allow the swampy areas to dry up and become fit for work.

Persistent rains increased considerably the difficulty of field work. The Andaman jungles and valley lands are almost a continuous tropical forest and abound in leeches, swamps and soft mud and the hill-tops are full of dense forests with trees about 150 feet high. Even the smaller trees are inextricably tangled with prolific creepers. Local *mazdoors* are seldom available. Labour can only be obtained from the Labour Officer from his labour force which is imported from India (Rānchi and Telugu Districts). These labourers are generally employed on the docks and are not accustomed to the hardships of the forests. Gangs had, therefore, to be changed pretty often for clearing the jungles for reconnaissance. The Survey of India *khalāsīs* proved to be of great help in this arduous task of clearing difficult jungles in pouring rains but they were not enough in numbers.

Mr. S. K. Bose (Surveyor) arrived with levelling and special river crossing equipment on 26th November 1950. Mr. A. K. Bhattacharjee and Mr. Bose started levelling work on 1st December, 1950. Level lines from the old Ross Bench-mark, carrying the level across the sea from Ross Island to Aberdeen Jetty, were carried out. Another river crossing was effected to Chatham to complete a levelling circuit. Precision levelling methods were adopted and eight 'C' Type bench-marks and one 'B' Type bench-mark were laid and handed over to the P.W.D. for preservation and maintenance. Three G.T. stations—Ross Air Raid shelter station, Haughton and Chatham Astro. station were also connected by levelling. Shortage of trained *khalāsis* was a great handicap throughout the field. Details of this levelling are given in Chapter III.

(*c*) *Narrative of the Observation Party.*—Triangulation observations were started on 2nd January, 1951, the base connections being observed first. The weather became adverse towards the end of January and early February. A transport crisis in boats, and launches developed in January. ML 'Elsa' was under repairs and ML "Molly" ran aground while carrying heliotropes to Tarmugli. Difficulty of posting of heliotropes to island stations considerably slowed down observations, which in many cases had to be taken in broken rounds to suit the posting of heliotropes.

Fortunately the Indian Naval Ship 'Kukri' of the Marine Survey of India arrived in Port Blair on 26th January, 1951 for the survey of the Duncan Passage. The Commander kindly agreed to transport heliotropes to stations in the southern islands during his week-end runs between Port Blair and Duncan Passage. This relieved the transport situation to some extent and observation for stations lying south of Port Blair were planned so as to avail of the facilities offered by 'Kukri'. These observations were completed on 21st March, 1951. A subsidiary station on Sisters West which was the origin of the Duncan Passage survey by I. N. S. Kukri was also observed and connected.

The field season was closed on 29th April, 1951 after observing the Barewell—Twins ray. The Tarmugli—Twins ray could not

be cleared as after the 28th April it started raining practically every day and further observations were not possible. The detachment assembled in Port Blair in the first week of May and left for India by the *S.S. Maharaja* on the 13th May 1951.

Most of the personnel suffered from malaria and malnutrition and from sores due to leech bites and ticks. Night blindness seemed to be a common malady with many *mazdoors* after some time. Green vegetables are seldom available. The hospital at Port Blair is well equipped and was a great boon to the Survey Party.

9. Ferrar Ganj Base-line.—The choice of a site for the base-line presented considerable difficulty on account of unsuitable terrain. The entire area is heavily forested and consists of hills separated by narrow valleys. After a lot of reconnoitring, a flat stretch was selected near Ferrar Ganj where a base about 2½ miles long was laid out.

Its southern end is situated in the swampy paddy fields about one mile north-west of the Tusonābād village and its northern end is in the compound of the Horticulturist's garden in Ferrar Ganj.

For the first half mile from the south station the base line runs through swampy paddy fields. The next mile is through portions of thick jungle and involves crossing of some *nālās*. The clearance of the jungle to make the route clear for the movement of the squad involved much time and labour. The rest of the base-line was again through swampy paddy fields and passed over some high mounds covered with jungle. A certain amount of digging and raising had to be done in this elevated portion to decrease the relative height of the two pegs of individual 24-metre bays. The demarcation of the base was carried out from 21st February to 26th March 1951.

The descriptions of the terminal stations of the base-line is given in the next para. A *pakka* station mark was laid at the central base station and intermediate points, lying on the two halves of the base at about half-mile or shorter intervisible distances were surveyed and demarcated by flags. Alignment of the flags was carried out with the help of a Wild theodolite—the flags being shifted to fall on the exact base-line.

10. Description of terminal stations.—(*a*) *Ferrar Ganj Base South Station.*—The station mark consists of a brass plug set in cement concrete about an inch above the upper surface of a stone embedded in a circular masonry pillar 32 inches in diameter and 3 feet 6 inches high. A ring of masonry one foot thick and of the same height as the pillar, surrounds it, but is separated from it by an annular space 3 inches wide. Vertically below the upper mark-stone there is another brass plug with cross mark on the upper surface of the stone embedded in the centre with cement and concrete. There is a tubular cavity between the two marks. The distance between the two marks is 3 feet 1¼ inches. Around the masonry ring there is a platform of earth and stones 12 feet square and of the same height as the pillar.

The station is situated on the elevated space of hard ground in the open paddy field about one mile north-west of Tusonābād village.

(*b*) *Ferrar Ganj Base North Station.*—The mark consists of a brass plug set on the upper surface of a stone embedded by cement concrete and about an inch above the top of a circular masonry pillar 32 inches in diameter and 3 feet 6 inches high. A ring of masonry one foot thick and of the same height as the pillar surrounds it but is separated from it by an annular space 3 inches wide. Vertically below the upper mark-stone there is another brass plug with the cross mark embedded in the centre of the rock. There is a tubular cavity between the two marks. The distance of the lower mark from the upper one is 3 feet. Around the masonry ring is a platform of earth and stones 12 feet square.

The station is situated in the garden of P.W.D. Horticulturist's bungalow in Ferrar Ganj approachable by a motor road from Port Blair which is at a distance of 26 miles.

11. System of base measurement.—The system of measurement was by invar wires in catenary as in the previous years.

Wire Nos. 244 and 252 were used for south-to-north measure and Nos. 248 and 1037 for the reverse direction. Wire No. 1038 was used as sub-standard for daily comparisons of the working wires and No. 245 as the standard for the comparison of the field sub-standards. Comparisons with the field sub-standard were made daily some time before and after the work in such proportion as to make the mean temperature of comparison the same as the mean temperature at which the base had been measured. Wire No. 246 was taken as a spare for use in case of a casualty.

The wires were standardized against the Dehra Dūn 24-metre comparator before and after the field season and full details regarding their lengths as well as their coefficients of expansion are given in Chapter II (Observatories). It will be seen from the results that the wires have held their lengths satisfactorily.

These wires were used with 10 tripods under a tension of 10 kgms. Before the measurement was started, the positions for the tripods were laid out by marks on pegs, accurately aligned and at approximately the correct intervals. The heights of these pegs were determined by spirit-levelling. During measurement the heights of the tripods above the pegs were taken by the observer and an assistant and were compared then and there. When the rise or fall exceeded about 4 feet, this was checked by direct levelling between the register heads of the tripods.

The measurement of the base was carried out by Mr. U. D. Mamgain and Mr. A. K. Bhattacharjee assisted by two computers and 24 *khalāsīs* from 31st March to 15th April, 1951. The average out-turn was 34 bays per day. Temperature ranged from 22°C to 37°C. Mr. A. K. Bhattacharjee left for India with the wires for recalibration on the 18th April, 1951.

12. **Results of base measurement.**—The final results are tabulated below :—

Wire / Section No.	South to North (Fore) No. 244	South to North (Fore) No. 252	North to South (Back) No. 1037	North to South (Back) No. 248	Mean value of each section
	metres	metres	metres	metres	metres
I	745·0352	745·0360	745·0357	745·0343	745·0353
II	688·4089	688·4103	688·4096	688·4091	688·4095
III	332·9712	332·9718	332·9730	332·9731	332·9723
Total I to III	1766·4153	1766·4181	1766·4183	1766·4165	1766·4171
IV	1153·6208	1153·6219	1153·6259	1153·6238	1153·6231
V	583·1067	583·1076	583·1044	583·1036	583·1056
VI	303·1708	303·1714	303·1696	303·1684	303·1700
VII	71·9030	71·9032	71·9031	71·9030	71·9031
Total IV to VII	2111·8013	2111·8041	2111·8030	2111·7988	2111·8018
Sum of two halves	3878·2166	3878·2222	3878·2213	3878·2153	3878·2189

The discrepancy between the south-to-north and north-to-south measures is 1 : 3,525,000.

The measured length of the base is 3878 ·2189 metres. This length is reduced to Indian feet by the following conversion factors :

1 standard yard = 0 ·914 399 20 metres
1 Indian foot = 0 ·333 331 886 standard yards.

The reduced length is 12723 ·8817 Indian feet.

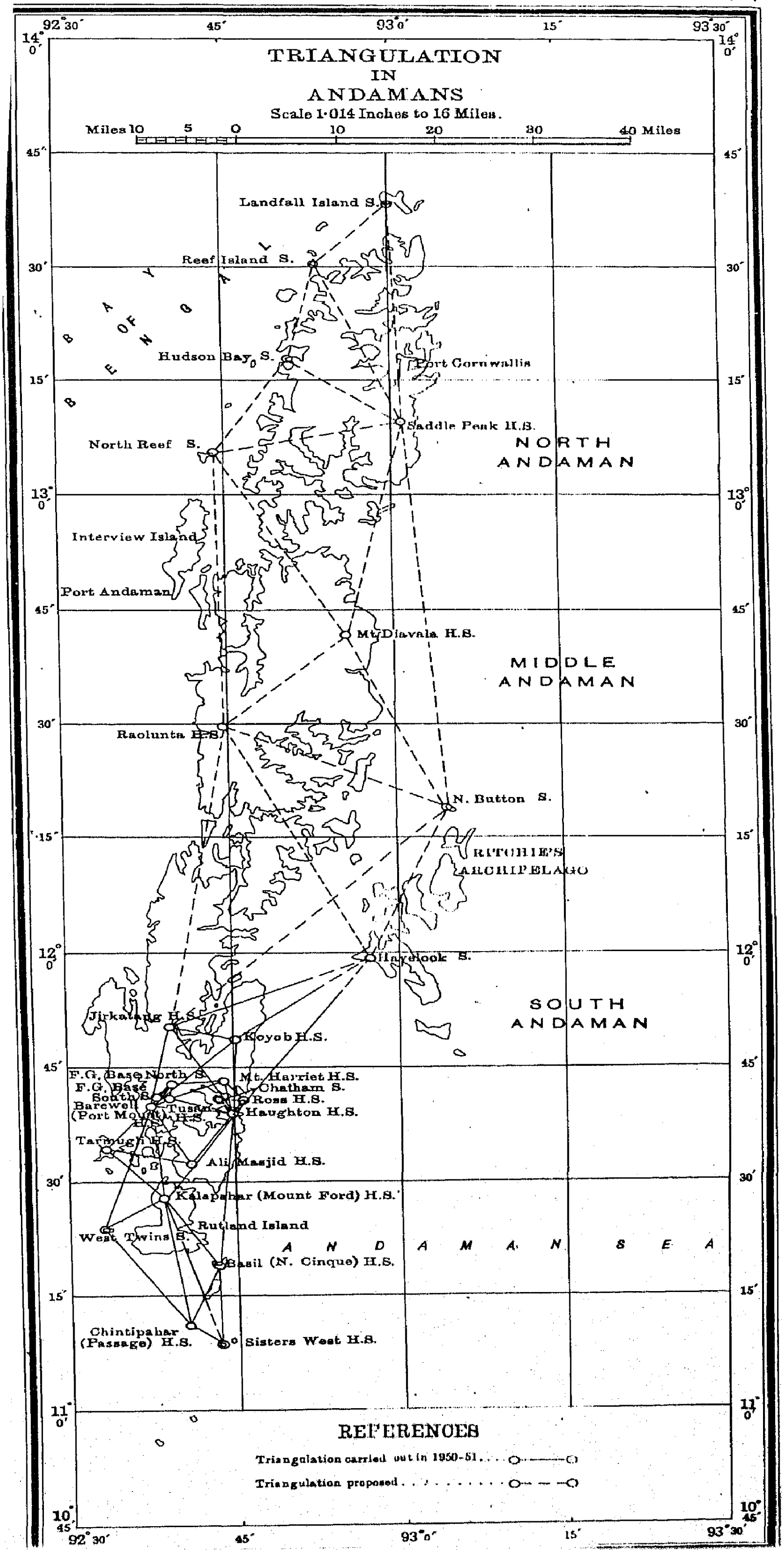
In reducing the length of the base to spheroidal level, the height of the geoid above the Everest spheroid is required. This is not known as the triangulation of Andamans has not been connected to that of India. But a value of 90 feet has been assumed on the assumption that the geoid coincides with the International spheroid in this area.

Reduced to spheroid level, the length of the base is 12723 ·8046 Indian feet.

13. **Datum of Co-ordinates and Azimuth.**—A brief account of the older triangulation in the Andamans and Nicobars carried out in 1883–86 is given in Technical Report 1948–49, Part III, Chapter I, para 5. The datum station for latitudes and longitudes is the astronomical observatory at Chatham Island. The values of co-ordinates of this Observatory as determined by Mr. Nicholson of the Survey of India in 1861 were

Latitude 11° 41′ 13″ N.
Longitude 92° 42′ 44″ E.

Chart V


TRIANGULATION
IN
ANDAMANS
Scale 1·014 Inches to 16 Miles.
Miles 10 5 0 10 20 30 40 Miles
92°30′ 45′ 93°0′ 15′ 93°30′
14° 0′
45′
30′
15′
13° 0′
45′
30′
15′
12° 0′
45′
30′
15′
11° 0′
10° 45′
Landfall Island S.
Reef Island S.
Hudson Bay S.
Port Cornwallis
Saddle Peak H.S.
North Reef S.
NORTH
ANDAMAN
Interview Island
Port Andaman
Mt. Diavala H.S.
MIDDLE
ANDAMAN
Raolunta H.S.
N. Button S.
RITCHIE'S
ARCHIPELAGO
Havelock S.
SOUTH
ANDAMAN
Jirkatang H.S.
Koyob H.S.
F.G. Base North S.
F.G. Base South S.
Barewell (Port Mount) H.S.
Tusna H.S.
Mt. Harriet H.S.
Chatham S.
Ross H.S.
Haughton H.S.
Tarmugli H.S.
Ali Masjid H.S.
Kalapahar (Mount Ford) H.S.
Rutland Island
West Twins S.
Basil (N. Cinque) H.S.
Chintipahar (Passage) H.S.
Sisters West H.S.
BAY OF BENGAL
ANDAMAN SEA
REFERENCES
Triangulation carried out in 1950-51
Triangulation proposed

The latitude was determined from 162 meridional zenith distances and was of a high degree of accuracy.

The longitude was obtained directly with respect to Greenwich from 41 lunar culminations. It was later realized that this was an inaccurate method. Accordingly in 1899, another determination of the longitude was made with respect to a G.T. point in Burma (Diamond Island, Flagstaff) by transport of chronometers. The value was found to be greater than the earlier value given above by 1′ 16″ and was considered to be an improvement on the older value and some of the triangulation data and charts were corrected to accord with it. This value was, however, by no means very reliable and could not be regarded as final. The redetermination of the astronomical longitude of Chatham Observatory by the modern method was, therefore, considered to be very desirable.

The observations were carried out by Mr. J. B. Mathur with an astrolabe on three nights of 31st October, 1950, 1st November, 1950 and 2nd November, 1950. Details of the observations are given in Chapter V. The values of the latitude and longitude obtained are as follows :—

Latitude 11° 41′ 13″·04 $\pm$ 0″·5 N.
Longitude 92° 43′ 30″·32 $\pm$ 0″·3 E.

The new value of longitude lies midway between the 1861 and 1899 values.

The initial azimuth for the new series of geodetic triangulation was obtained from 18 observations of Polaris on 23rd November 1950 and 20 observations on 26th November 1950.

The results were as follows :—

Place	Reference mark	Date	Azimuth
			° ′ ″ ″
Chatham Observatory	Haughton H.S.	23-11-50	328 47 19·6 $\pm$ 0·2
		26-11-50	328 47 19·9 $\pm$ 0·4
		Mean ..	328 47 19·7

The above values of the astronomical datum place the triangulation of the Andamans on a satisfactory independent basis. When opportunity occurs, it would be desirable to connect this triangulation to the Primary Triangulation of India.

14. **Details of the Andaman Triangulation.**—Chart V shows the complete layout of the proposed new geodetic triangulation of the Andamans. This consists of 27 stations of which only 17 stations could be occupied this year. Due to the configuration of the islands coupled with transport difficulties and inaccessibility of certain peaks, some elongated figures had inevitably to be introduced.

The observations were carried out both during day and night with a Geodetic Tavistock theodolite No. V0528 from 2nd January, 1951 to 28th April, 1951. Horizontal angles were measured on 8 zeroes mostly with three sets on each zero.

Vertical angles (two sets) were observed at the time of minimum refraction.

15. Crinoline chain traverses of the Car Nicobar Islands.—(*a*) *Narrative.*—A detachment under Major C. M. Sahni, consisting, besides the Officer-in-Charge, of one Surveyor (Mr. P. N. Sanyal) and 8 *khalāsīs*—was detailed to carry out the prepointing for the air survey of the Car Nicobar Island. For planimetry, control points were required at a spacing of 3½ miles and for heights a density of one point per every ¾ mile or so was aimed at.

It was planned to carry out a traverse comprising of two main circuits (Periphery and centre of the Island) using two crinoline chains (100 yds. and 110 yds.) and a glass arc theodolite (Wild). Astronomical azimuths from stars were to be observed every 8 to 10 miles.

The detachment left Dehra Dūn on 15th October, 1950 and sailed from Madras on 22nd October, disembarking at Car Nicobar on 25th October. It then sailed for Nancowry group of Islands on 1st November, and returned to Car Nicobar on 8th November.

The detachment was well provided with prophylactic and curative medicines, for malaria and snake-bites. Major Sahni flew back to India after completion of work on 11th April, 1951 and the rest of the detachment returned by sea on 12th May, 1951.

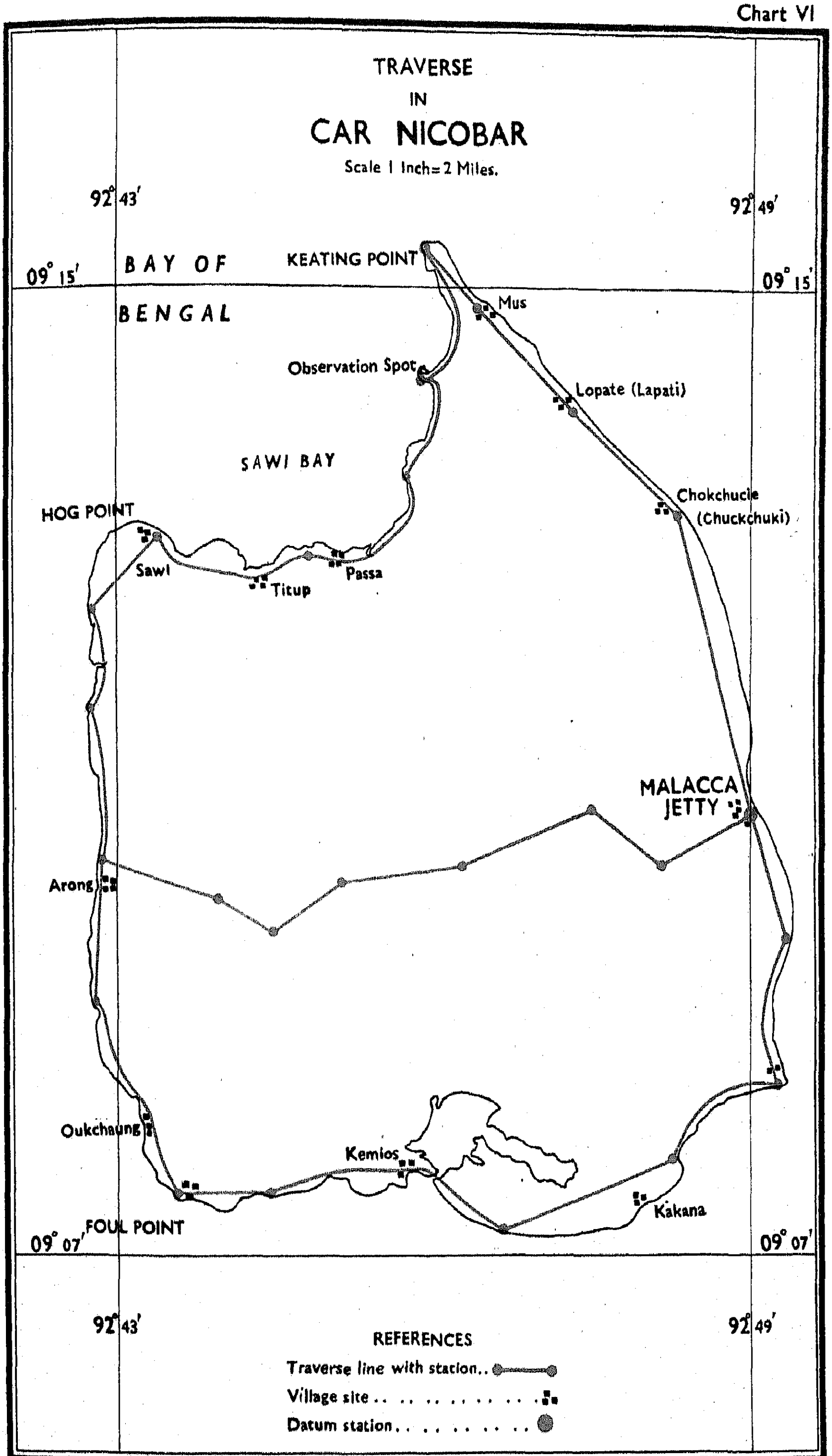
(*b*) *Nature of the Island.*—The island of Car Nicobar is 54 square miles in area and is about 140 miles from the Andamans. It has low hills in the centre, sloping gently in all directions. The eastern side is much more fertile than the western, where there are a number of low depressions and swamps. There is a coral reef all round the island extending from about 100 to 300 feet.

The island has a typically tropical appearance abounding in coconut trees. Unlike the Andamans, there are no commercially valuable trees. The forests consist of trees 20 to 30 feet high inter-mingled with thick tall trees 60 to 80 feet high. On the eastern coast bananas and *papitas* grow in abundance. On little cleared patches, the locals grow yam, sugar-cane and chillies. There are a few mango and jack fruit trees.

A number of roads were made by the Japanese during their occupation. Only the periphery road is maintained now. Japanese concrete bunkers and equipment can be seen all over the island.

The Nicobarese number about 9,000. They are an intelligent, well-built and care-free people. Most of them are Christians and have a church in every village. Government has started schools in the villages also ; and many can speak Hindustāni. Some of them have been successfully trained as nursing orderlies, school teachers, drivers, tailors and carpenters.

Chart VI



Reg. No. 43 D/NC. D'52 (G.& T.C.,1"=2 Miles)-375. Printed at the Survey of India Offices (P. Z. O.).

Each village has a headman whose orders are implicitly obeyed by all. For engaging labourers they should always be contacted. Nicobarese are very suspicious of all visitors; a sympathetic and tolerant attitude makes them very friendly.

The island is full of snakes, but few are poisonous. There are lots of pythons in all the Nicobarese group of islands. Local people rear pigs and chickens and keep dogs and cats as pets. There are no animals which yield milk.

(*c*) *Weather*.—It rains throughout the year in these islands and except when raining the climate is very hot. The months with the minimum rainfall of 2 ·5 to 4 inches are February, March and April. Till the middle of January, rain is frequent and the monsoon breaks in early May. The sky is always cloudy. The wind is north-easterly from January to May and south-westerly in the remaining months.

(*d*) *Transport and camping sites*.—The periphery road affords easy access to the whole island. As a protection against snakes, it was necessary to stay in local huts which are constructed 3 to 5 feet above the ground.

(*e*) *Marking sites of control points*.—Sites for control points and routes of traverse and level lines had to be selected so that the least jungle clearing was involved. The Nicobarese were reluctant to cut their coconut trees and demanded heavy compensation for each tree.

At control points, clearings of 80 to 100 feet diameter were made. To distinguish them from the clearings in gardens a white cross (whitewash or sand) with arms 60 feet by 10 feet, was made. If a hut in a little clearing was available, the cross was painted on its thatched roof with the arms extending to the ground. This extension of the arms had to be protected from the children and the pigs by putting a fence round it. Painting of the crosses was left to be done a few days before the photography was to commence.

Planimetric control points around the coast which had to be sited on sand had the arms of the cross marked with branches of trees, as for example, at Chuckchuki, Lapati and Mus. These came out very well on the photographs.

Since heavy jungle clearing was required, for triangulation and clinometric heights, recourse was taken to traverse and levelling. Periphery traverse if run along the road required a lot of cutting of coconut trees, to get longer rays: it was therefore run along the coast-line. Here many stations had to be made on the coral reef which was under 4 to 5 feet of water at high tide. Traverse could only be run during low tide.

The station of origin as well as that for tidal observation was selected at Malacca Jetty. 29 days' tidal observations were taken by the Indian Navy.

(*f*) *Health.*—Health of the detachment remained good till December. After that malaria attacks became frequent. One contingent *khalāsi* was bitten by a snake, which fortunately was non-poisonous.

(*g*) *Traverse observations.*—Horizontal angles were observed on two zeroes with two sets on each zero. Vertical angles were observed at the time of minimum refraction on both faces—one set only.

Two crinoline chains of length 100 and 110 yards respectively were used. The progress in the beginning was about 1½ miles per day, as many distances had to be re-chained. As the squad gathered experience, however, distances up to 3½ miles per day could be easily chained.

Stations were made in the sand by driving in thick wooden pickets 6 to 7 feet long, rammed with coral and a nail marking its centre. On coral reef, iron rods 2 to 3 feet long and ¾ inch thick were hammered in and a cross filed to mark its centre. Flags on 10 to 12 feet long bamboos were erected at all stations.

The details of the traverse are as follows :—

	Periphery Traverse	Central Traverse
Length of traverse ..	28·49 miles	10·82 miles
Total number of stations ..	50	186 (excluding starting and closing stations).
Closing error in Easting ..	1·5 yds.	2·8 yds.
,, ,, ,, Northing ..	0·9 yds.	0·7 yds.
Number of Astro. azimuth stations	5	8 (excluding starting and closing stations).

It was not possible to do a precise astronomic fixation of the datum. The co-ordinates have accordingly been computed in terms of Malacca Jetty.

Levelling.—Total outturn of tertiary levelling was 75 miles. A tertiary level line was run along the periphery coastal road. From this framework, branch lines were run to find heights of control points. Traverse stations were also connected to the level lines frequently. Details are given in Chapter III.

Chapter II

OBSERVATORIES

BY B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

16. Standards of Length.—Eight invar wires were standardized in the 24-metre comparator at Dehra Dūn for the measurement of the geodetic base in the Andaman Islands. The 4-metre invar bar was also calibrated against the 1-metre nickel bar. Details of the observations are given below. It will be seen that the bars and wires have maintained their previous lengths very satisfactorily. The observers were Messrs. V. P. Sharma and A. K. Bhattacharjee.

The 4-metre invar bar has been measured in 4 sections which are reduced to a common temperature of 24°·3C. This bar has three sets of graduations on it—one on its edge A, the other on edge B and the third on Baros plugs in the centre. The details of comparison with the 1-metre nickel bar are given below.

(*a*) Invar 4-m (Baros plugs) *minus* Nickel 1-m.—
First metre (0 to 1) of invar bar.

Date	Temperature	A. K. B.	V. P. S.
16-8-50	T_1 = 26°·09C T_N = 26°·07C	−0·2816 mm. ·2817 ·2820 ·2810 ·2826 ·2830 ·2853 ·2821	−0·2803 mm. ·2825 ·2814 ·2800 ·2825 ·2843 ·2835 ·2826
	Mean	−0·2824 mm.	−0·2821 mm.

Reputed length of nickel at 26°·07C = 1 m. + 0·3435 mm. (derived from N.P.L. certificate 1947)

Observed invar *minus* nickel = − 0·2823 mm.

∴ Length of the invar at 26°·09C = 1 m. + 0·0612 mm.

The expansion equation of invar is

$$L_T = L_0 \;(1 + 0\cdot000\ 001\ 450t - 0\cdot000\ 000\ 000\ 5t^2)$$

which gives the length of this section of the invar bar at 24°·3C to be = 1 m. + 0·0587 mm.

Second metre (1 to 2) of invar bar.

Date	Temperature	A. K. B.	V. P. S.
14-8-50	T_1 = 26°·29C T_N = 26°·27C	−0·2932 mm. ·2951 ·2937 ·2945 ·2913 ·2904 ·2918 ·2929	−0·2908 mm. ·2946 ·2934 ·2923 ·2914 ·2889 ·2903 ·2940
	Mean	−0·2929 mm.	−0·2920 mm.

Reputed length of nickel = 1 m. + 0·3460 mm.
Observed invar *minus* nickel = — 0·2924 mm.
Length of the invar at 26°·29C = 1 m. + 0·0536 mm.
.Length of the invar at 24°·3C = 1 m. + 0·0508 mm.

Third metre (2 to 3) of invar bar.

Date	Temperature	A. K. B.	V. P. S.
13-8-50	T_1 = 26°·30C T_N = 26°·29C	−0·2930 mm. ·2915 ·2925 ·2885 ·2899 ·2870 ·2884 ·2883	−0·2902 mm. ·2924 ·2924 ·2906 ·2892 ·2879 ·2884 ·2896
	Mean	−0·2899 mm.	−0·2901 mm.

Reputed length of nickel = 1 m. + 0·3463 mm.
Observed invar *minus* nickel = — 0·2900 mm.
Length of the invar at 26°·30C = 1 m. + 0·0563 mm.
.Length of the invar at 24°·3C = 1 m. + 0·0534 mm.

Fourth metre (3 to 4) of invar bar.

Date	Temperature	A. K. B.	V. P. S.
12-8-50	T_1 = 26°·44C T_N = 26°·43C	−0·2821 mm. ·2830 ·2843 ·2825 ·2873 ·2882 ·2876 ·2850	−0·2824 mm. ·2831 ·2858 ·2815 ·2895 ·2874 ·2880 ·2848
	Mean	−0·2850 mm.	−0·2853 mm.

Reputed length of nickel = 1 m. + 0·3481 mm.
Observed invar *minus* nickel = — 0·2851 mm.
Length of the invar at 26°·43C = 1 m. + 0·0630 mm.
.Length of the invar at 24°·3C = 1 m. + 0·0600 mm.

Combining the four sections of the invar bar we get the total length of the bar (Baros plugs) as 4 m. + 0·2228 mm. at 24°·3C.

The lengths as determined on previous occasions are :—

Year	*Length*
1931	4000·2226 mm.
1934	4000·2235 mm.
1937	4000·2192 mm.
1945	4000·2474 mm.
1949	4000·2187 mm.

In the 1945 length determination the bars were not immersed under water and it is presumed that the observed temperatures do not show the correct temperatures of the bars.

The 1949 length was determined by the same set of observers and the change in length is of the order of one in a million. The bar can thus be regarded as having maintained its length well.

(*b*) 4-m Invar. Edge B *minus* Baros plugs.-

Date	A. K. B.	V. P. S.
19–8–50	—0·0064 mm. ·0046 ·0031 ·0034	—0·0066 mm. ·0036 ·0041 ·0039
Mean	—0·0045 mm.	—0·0046 mm.
	General mean	—0·0045 mm.

Length of the 4-m invar (Baros plugs) at 24°·3C = 4 m. + 0·2228 mm.
Length of the 4-m invar Edge B at 24°·3C = 4 m. + 0·2183 mm.
and length of 4-metre invar Edge B at 28°C = 4 m. + 0·2394 mm.

The previous determinations of Edge B are.

Year	*Lengths*
1914	4 m. + 0·2060 mm
1930	0·2376 mm
1934	0·2395 mm
1937	0·2417 mm
1949	0·2411 mm

(*c*) 4-m Invar. Edge B *minus* Edge A.—

Date	A. K. B.	V. P. S.
19-8-50	−0·0088 mm. ·0068 ·0040 ·0070	−0·0088 mm. ·0077 ·0085 ·0107
Mean	−0·0066 mm.	−0·0089 mm.
	General mean	−0·0077 mm.

This value differs a bit widely from the previous determinations which are listed below :—

Year	*Edge B—Edge A*
1914 N.P.L.	+ 0·003 mm.
1930	+ 0·0038
1934	+ 0·0032
1937	+ 0·0042
1949	+ 0·0008

Accordingly the comparisons of (*b*) and (*c*) were repeated on three different days after the field season. The results are as below :—

4-m Invar. Edge B *minus* Baros plugs.—

Date	V. P. S.	A. K. B.
8-5-51	+0·0028 mm. ·0002 ·0002 ·0037 ·0037	+0·0032 mm. −0·0013 +0·0003 ·0056 ·0055
Mean	+0·0021 mm.	+0·0027 mm.
	General mean	+0·0024 mm.

4-m Invar. Edge B *minus* Edge A.-

Date	V. P. S.	A. K. B.
8-5-51	+0·0122 mm. ·0075 ·0097 ·0021 ·0074	+0·0105 mm. ·0039 ·0103 ·0051 ·0098
Mean	+0·0078 mm.	+0·0079 mm.
	General mean	+0·0079 mm.

4-m Invar. Edge B *minus* Baros plugs.-

Date	V. P. S.	A. K. B.
9-5-51	+0·0083 mm. + ·0074 + ·0033 + ·0015 − ·0002	+0·0096 mm. + ·0073 + ·0027 − ·0007 + ·0010
Mean	+0·0041 mm.	+0·0040 mm.
	General mean	+0·0041 mm.

4-m Invar. Edge B *minus* Edge A.-

Date	V. P. S.	A. K. B.
9-5-51	+0·0098 mm. ·0102 ·0129 ·0076 ·0113	+0·0109 mm. ·0118 ·0115 ·0074 ·0125
Mean	+0·0104 mm.	+0·0108 mm.
	General mean	+0·0106 mm.

4-m Invar. Edge B *minus* Edge A.—

Date	V. P. S.	A. K. B.
10-5-51	+0·0107 mm. ·0067 ·0114 ·0083	+0·0099 mm. ·0074 ·0111 ·0077
Mean	+0·0093 mm.	+0·0090 mm.
	General mean	+0·0092 mm.

4-m Invar. Edge B *minus* Baros plugs.-

Date	V. P. S.	A. K. B.
10-5-51	+0·0045 mm. ·0009 ·0032 ·0027	+0·0040 mm. ·0027 ·0037 ·0018
Mean	+0·0028 mm.	+0·0031 mm.
	General mean	+0·0029 mm.

The mean value of Edge B—Baros plugs is + 0·0031 mm. and of Edge B—Edge A is + 0·0092 mm.

Past experience has shown that comparisons of Edges A and B exhibit rather large changes from year to year. These are probably not real but are due mainly to the fact that edge marks A and B are of coarser grain than the Baros marks and direction of illumination can introduce large errors.

(*d*) 4-m Nickel-steel *minus* 4-m Invar Baros plugs.—

Date	Temperature	A. K. B.	V. P. S.
17-8-50	T_1 = 25°·91C T_{NS} = 25°·87C	+0·5468 mm. ·5469 ·5449 ·5460 ·5444 ·5454 ·5439 ·5442	+0·5479 mm. ·5478 ·5451 ·5440 ·5468 ·5422 ·5442 ·5447
	Mean	+0·5453 mm.	+0·5453 mm.
		Accepted mean	+0·5453 mm.

Accepted length of 4-m invar bar at 24°·3C = 4 m. + 0·2228 mm.
Length of 4-m invar bar at 25°·91C = 4 m. + 0·2320 mm.
Observed nickel-steel *minus* invar = + 0·5453 mm.
Length of 4-m nickel-steel at 25°·87C = 4 m. + 0·7773 mm.
Coefficient of expansion of nickel-steel = 0·000 007, 52 per °C
∴ Length of this bar at 24°·3C = 4 m. + 0·7301 mm.

17. **Coefficients of Expansion of 24-metre Invar wires.**—The coefficients of expansion of 24-m wires were determined in the field as follows :—

8 bays covering a length of 192 metres were laid on a flat bit of ground. *Pukka* brass plugs set in cement marked the ends of this line. In addition one *pukka* mark was also laid at a distance of 3 bays from one end.

The distance between the three brass plugs, both in fore and back direction, was measured during the highest and lowest temperature periods on one day and repeated on another day. The daily range of temperature in the Andaman Islands was, however, not enough, being only of the order of about 8°C. The results could only be used as gross check on the previous values obtained. The temperature coefficient found for different wires is given in the following table.

Length of 24 - metre Comparator, 1950-51

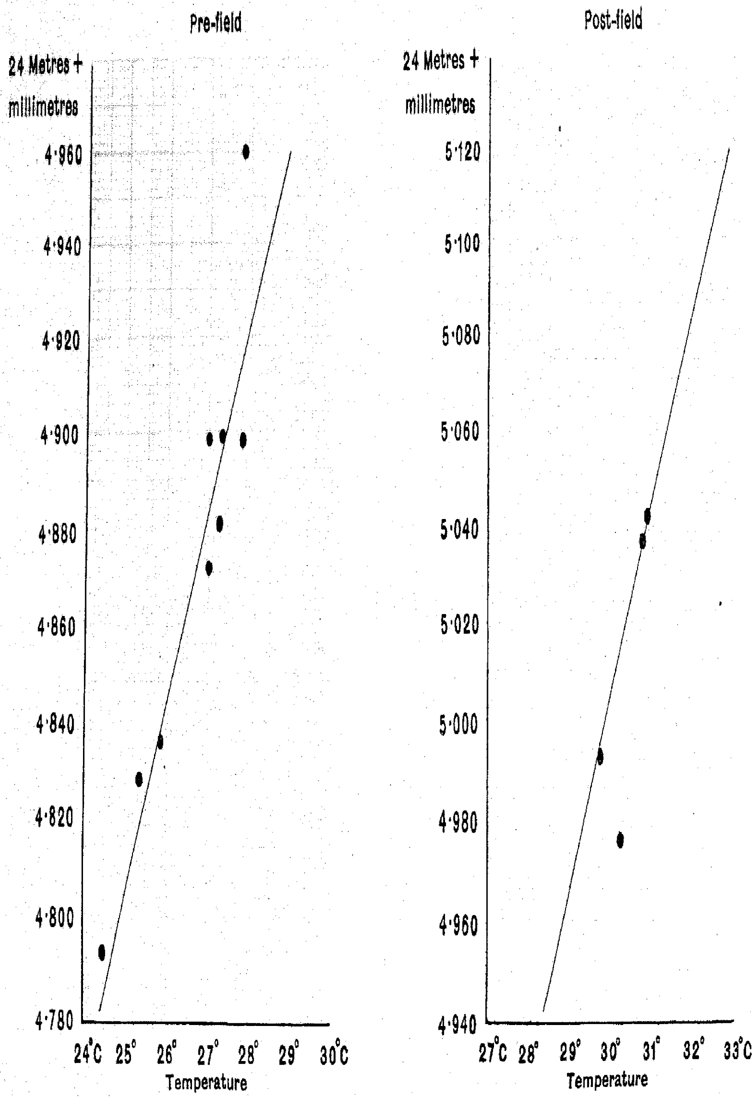


Plate VII

Reg. No. 46 D/M-G.D'52 (G.&T.C.)-375.
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Increase in mm. per 24 metres per 1°C.

Season \ Wire Nos.	1038	248	1037	252	244
15-4-51	−0·0024	−0·0062	−0·0011	−0·0063	+0·0035
1949	− ·0078	− ·0132	− ·0091	− ·0138	− ·0092
1934	+ ·0012	− ·0028	− ·0000	− ·0050	+ ·0058

The 1949 values have been used in the final computation of the length of the base.

Coefficients of expansion of 24-m wire Nos. 245 and 246 and the 4-m wire No. 28 are not known.

18. Lengths of Wires.—All the eight 24-m Invar wires, the 8-metre wire and the 4-metre tape were taken to the field and their lengths were determined, both before and after the field work against the 24-metre comparator at Dehra Dūn. In the field, daily comparisons were made with the sub-standard and twice a week with the standard and a close watch was kept on the working wires. The wires behaved well in the field.

The pairs of working wires were :—

	Invar wire Nos.
Fore Direction	244 and 252
Back Direction	248 and 1037
Sub-standard	1038
Standard	245
Spare	246

The lengths of the 24-metre comparator were determined in August 1950, and May 1951 with the 4-metre Invar and are shown in Plate VII.

The resulting lengths of the wires, pre and post-field, as determined from the length of the 24-metre comparator under tension of 10 kg. and freely suspended, are as follows :—

Millimetres in excess or defect on 24 metres at 28°C.

Date \ Wire Nos.	244	245	*246	247	248	252	1037	1038
August 1950 (pre-field) ..	−2·46	+0·86	−0·13	+1·51	+1·64	+3·08	+0·77	+0·75
May 1951 (post-field) ..	−2·52	+0·98	−0·12	+1·67	+1·74	+3·16	+0·70	+0·91
Mean ..	−2·49	+0·92	−0·12	+1·59	+1·69	+3·12	+0·74	+0·83

* Coefficient of expansion not known.

Lengths determined in previous years are :—

Millimetres in excess or defect on 24 metres at 28°C.

Year \ Wire Nos.	244	245	*246	247	248	252	1037	1038
1949	−2·43	+1·02	−0·129	+1·47	+1·71	+3·15	+0·78	+0·79
1937	−2·39	..	..	+1·54	+1·72	+3·08	..	..
1934	−2·36	..	..	+1·61	+1·73	+3·07	..	..
1930-31	−1·74	..	..	+1·03	+1·12	+2·41	..	..

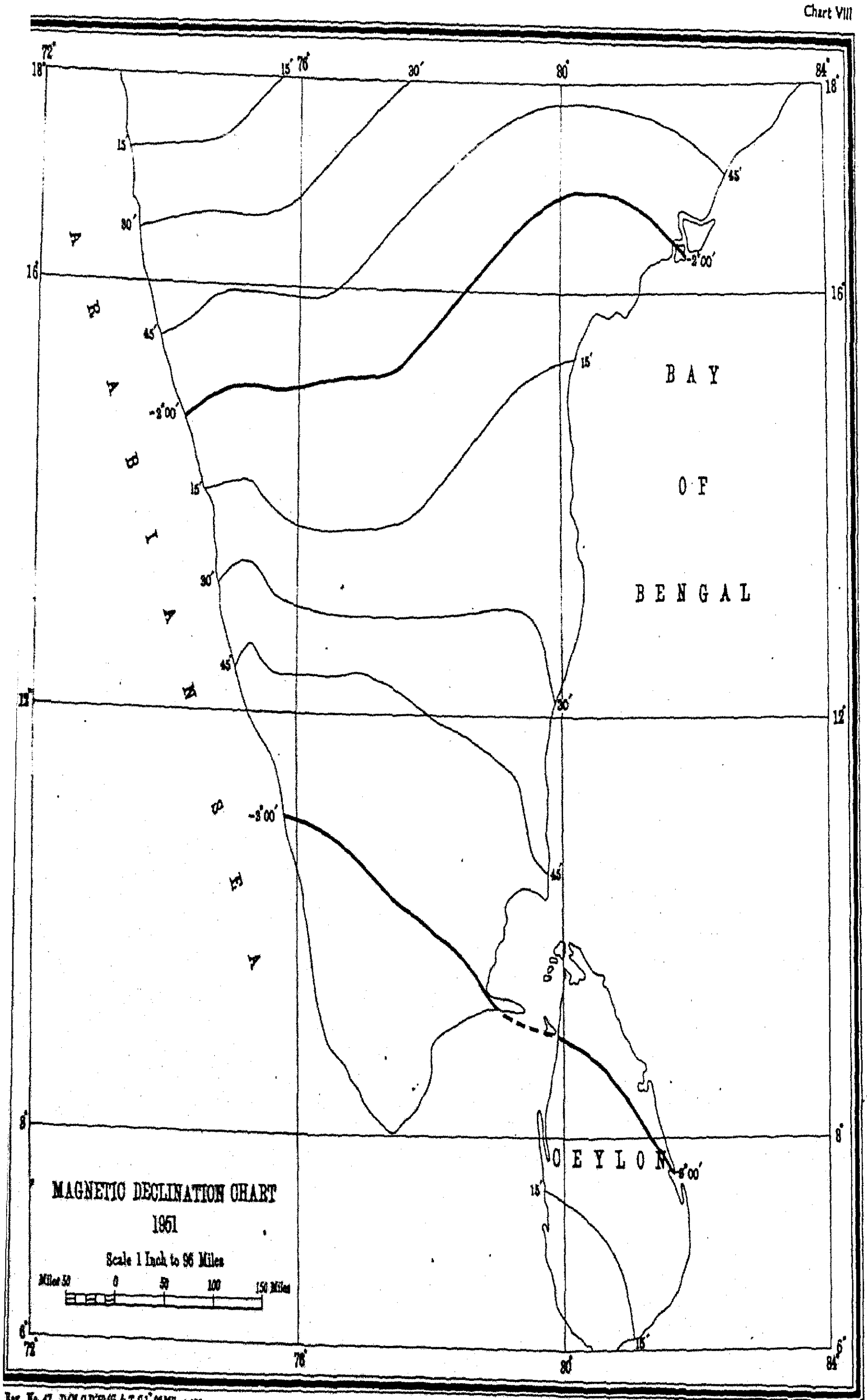
The lengths of the 4-m invar tape and 8-m invar wires are

Year \ Wire Nos.	4m. 28	8m. 983	Remarks
August 1950 .. Pre-field ..	4 m.+ 1·477 mm. at 27°·8C	8 m.+ 0·642 mm. at 28°·0C	Coefficient of expansion of 4 m. tape is not known. Coefficient of expansion of 8 m. wire is +0·00007 mm. per 1°C.
May 1951 .. Post-field ..	+1·4399 mm. at 28°·0C	+0·7056 mm. at 28°·0C	
Mean ..	+1·4584 mm. at 27°·9C	+0·6738 mm. at 28°·0C	

The previous determinations gave.—

Year	4-m tape No. 28	8-m wire No. 983 at 28°C
	4 m+	8 m+
1949	1·498 mm. at 27°·3C	0·692 mm.
1938	1·41 mm. at 29°·7C	0·640 mm.
1934	1·35 mm. at 28°C	0·684 mm.
1933	1·38 mm. at 28°C	0·632 mm.
N.P.L.	..	0·245 mm.

* Coefficient of expansion not known.



Reg. No. 47 D/M.C.D'52 (G. & T.C.1"=96 Miles)-375.

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Means of the pre and post-field values have been used for the reduction of the base. The final lengths accepted of the wires are as follows :—

Length	Wire No.	Standard correction at temperature °C	Temperature cœfficient	Remarks
		mm.	mm.	
24m	245	+0·92 at 28°C	Not known	Standard
,,	246	−0·12 ,,	,,	Spare
,,	244	−2·49 ,,	+0·0035	Fore measuring wire
,,	252	+3·12 ,,	−0·0063	Fore measuring wire
,,	248	+1·69 ,,	−0·0062	Back measuring wire
,,	1037	+0·74 ,,	−0·0011	Back measuring wire
,,	1038	+0·83 ,,	−0·0024	Substandard
8m	983	+0·6738 ,,	+ ·007	Fore and back measuring wires
4m	28	+1·4584 at 27°9C	Not known	

The 72-metre invar wire which is for use over wide stretches of ground to avoid slopes and creeks, was taken to the field, but occasion did not arise for its use.

19. **Magnetic Observations.**—Three Quartz Horizontal Magnetometers Nos. 17, 18 and 32, belonging to the International Association of Terrestrial Magnetism, were received in India for observations of the diurnal range of variation of the horizontal force near the Magnetic Equator. Detailed results of the measurements, as required by the Committee to promote such observations convened by the International Association of Terrestrial Magnetism and Electricity, have already been published in Technical Report Part III, 1949–50, Chapter VI.

The three Q.H.Ms. were also compared with the Kew Pattern instruments in use at Dehra Dūn and Alibag observatories. At Dehra Dūn, magnetometer No. 5 (with magnet 5B) displayed an index error of about -15γ with respect to the Q.H.Ms.; at Alibag magnetometer No. 7 had an index error of -34γ.

20. **Observations at Repeat Stations.**—In addition to the above comparisons, the Q.H.Ms. were used to measure horizontal force at 13 stations in South India. The provisional results are tabulated in Table 1. They are uncorrected for diurnal variation and perturbation. The final results will be published in the next Technical Report.

Chart VIII gives a revised up-to-date isogonal chart in the area south of latitude 16°, drawn as a result of these observations. This will also be modified suitably when the data is finally orrected.

TABLE 1.—*Repeat Stations Observed in 1950.*

Degree Sheet No.	Repeat Station No.	Name of Station	Latitude N.	Longitude E.	Height	Date of observation and Time (I.S.T.)	Observed* Declination	Date of observation and Time (I.S.T.)	Horizontal Force By Q.H.M.
			° ′ ″	° ′ ″	*feet*		° ′		*gammas*
47 B	..	Alibag observatory ..	18 38 17	72 52 26	20	18 5 50 (14:31 hrs.)	−0 46·8	18 5 50 (06:25 hrs.)	38465
48 M	VIII	Dhārwār	15 26 39	74 59 53	2400	28 7 50 (11:08 hrs.)	−1 53·0	28 7 50 (06:35 hrs.)	39515
48 O	XXXIX	Birūr	13 35 50	75 58 10	2500	23 7 50 (08:48 hrs.)	−2 16·0	23 7 50 (06:43 hrs.)	39822
49 M	XXXVIII	Cannanore ..	11 52 30	75 22 00	70	15 7 50 (17:25 hrs.)	−2 56·1	15 7 50 (18:16 hrs.)	39924
57 E	XXXV	Guntakal ..	15 10 48	77 22 57	1410	31 7 50 (08:47 hrs.)	−2 00·0	31 7 50 (06:02 hrs.)	39808
57 H	VII	Bangalore ..	12 58 43	77 35 26	3000	9 7 50 (09:00 hrs.)	−2 24·9	9 7 50 (06:36 hrs.)	40215
57 O	XXXVI	Arkonam ..	13 04 30	79 40 20	300	5 7 50 (17:39 hrs.)	−2 27·4	5 7 50 (18:23 hrs.)	40368
58 F	..	Kodaikānal observatory	10 13 50	77 27 46	7550	26 5 50 (10:25 hrs.)	−2 02·9	26 5 50 (06:38 hrs.)	39328
58 H	XLIV	Tinnevelly ..	8 43 42	77 42 57	130	6 6 50 (09:23 hrs.)	−3 08·0	6 6 50 (06:08 hrs.)	39887
58 N	XLVI	Tanjore	10 45 47	79 08 26	190	12 6 50 (09:03 hrs.)	−2 52·4	12 6 50 (06:18 hrs.)	40102
58 O	XLV	Mandapam ..	9 16 45	79 07 50	0	2 6 50 (09:44 hrs.)	−2 59·0	2 6 50 (06:15 hrs.)	40076
65 D	XLVIII	Bezwāda ..	16 31 22	80 37 40	70	6 8 50 (15:49 hrs.)	−2 09·2	Not observed	..
66 C	XXXVII	Perambūr ..	13 06 40	80 15 00	10	28 6 50 (09:00 hrs.)	−2 18·2	28 6 50 (06:28 hrs.)	40259
68 B	LXXV	Galle (Ceylon) ..	6 01 47	80 12 17	10	18 6 50 (09:24 hrs.)	−3 27·7	18 6 50 (06:12 hrs.)	39739

* Uncorrected for diurnal variations and perturbations.

NOTE :—Observations for declination were done with Kew Pattern Magnetometer No. 5 with suspension magnet No. 5B.

21. Meteorological and Seismological Observations.—The usual meteorological observations at 08½ and 17½ hours have been taken throughout the year. The meteorological data for Dehra Dūn have been supplied to various local civil and military offices. The original meteorological monthly records were sent to the Director, Regional Meteorological Centre, New Delhi.

The Omori Seismograph was in operation throughout the year. It was cleaned and reset in June 1951. Data of earthquake records was supplied to the Director-General of Observatories for publication in the monthly Seismological Bulletin.

22. Test, Calibration and Repairs of Instruments.—This Directorate now controls the issue, procurement and allotment of all precision instruments of the Department. As far as possible, the precision instruments are repaired in the observatory workshop.

During the year under report instruments of a total stock value of Rs. 1,83,000 were repaired. These consisted of 17 glass arc theodolites, 22 vernier theodolites, 24 levels, 22 barometers, 24 calculating machines, 46 binoculars, 17 watches, 53 magnetic compasses, 12 prismatic compasses, stereo comparators, projectoscopes and various other survey instruments. The tide predicting machine, the seismograph and other geodetic instruments were attended to and kept in working order.

20-meter tapes, levelling staves, 10 feet standard tapes, barometers and levels were calibrated. Tests on performance of many instruments sent by S.O.S. were carried out.

Four Radio receiving sets (model NC 100 ASD) were procured from American Disposals for the reception of time signals. These sets have frequency range of 200 to 400 kilocycles and 1,300 to 30,000 kilocycles and can be worked on a power supply of 115 volts, 50–60 cycles or 115 volts–25 cycles. These are being converted into battery run sets, so that they may be worked in the field in place of the antiquated R.P. 11 Marconi set.

A precision lathe has been set up in the workshop which can turn out footscrews for the theodolites and micrometer screws of accurate pitch.

23. Miscellaneous.—

(i) Various field detachments of Geodetic and Training Circle were supplied with instruments for field season 1950–51.

(ii) Delicate instruments installed in observatories were maintained in good condition and adjustment.

(iii) Annual examination of all surveying instruments of units and detachments at the close of field work was carried out.

(iv) Practice observations were carried out in Geodetic Base measurement and Triangulation observation for the benefit of the trainee officers in Dehra Dūn.

(v) Computation of Laplace observations and origin fixation in the Andaman Islands were scrutinized.

CHAPTER III

LEVELLING

BY B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

24. General.—During the period under report nine detachments were employed, two on levelling of high precision, one on precision levelling in the Andamans and seven on secondary levelling. A circuit of about 140 miles of tertiary levelling was also carried out in the Car Nicobar Island.

The two high precision levelling detachments carried out the back levelling of the line from Hubli to Kolhāpur, the fore levelling of which was done in 1947–49. This completes the re-observation of the older lines of levelling from Bombay to Kārwār.

The line from Kolhāpur to Raichūr via Wādi was observed in both fore and back directions. This line also forms part of the high precision level net of India. Part of the line from Kolhāpur to Raichūr serves the purpose of providing height datum for the levelling for the Koyna Irrigation Project. Two branch-lines one from Mirāj to Karād and the other from Mamdāpur to Muddebihāl were also run for the same purpose.

The cost of running these branch-lines and a part of the cost of the main line were paid for by the Bombay Government.

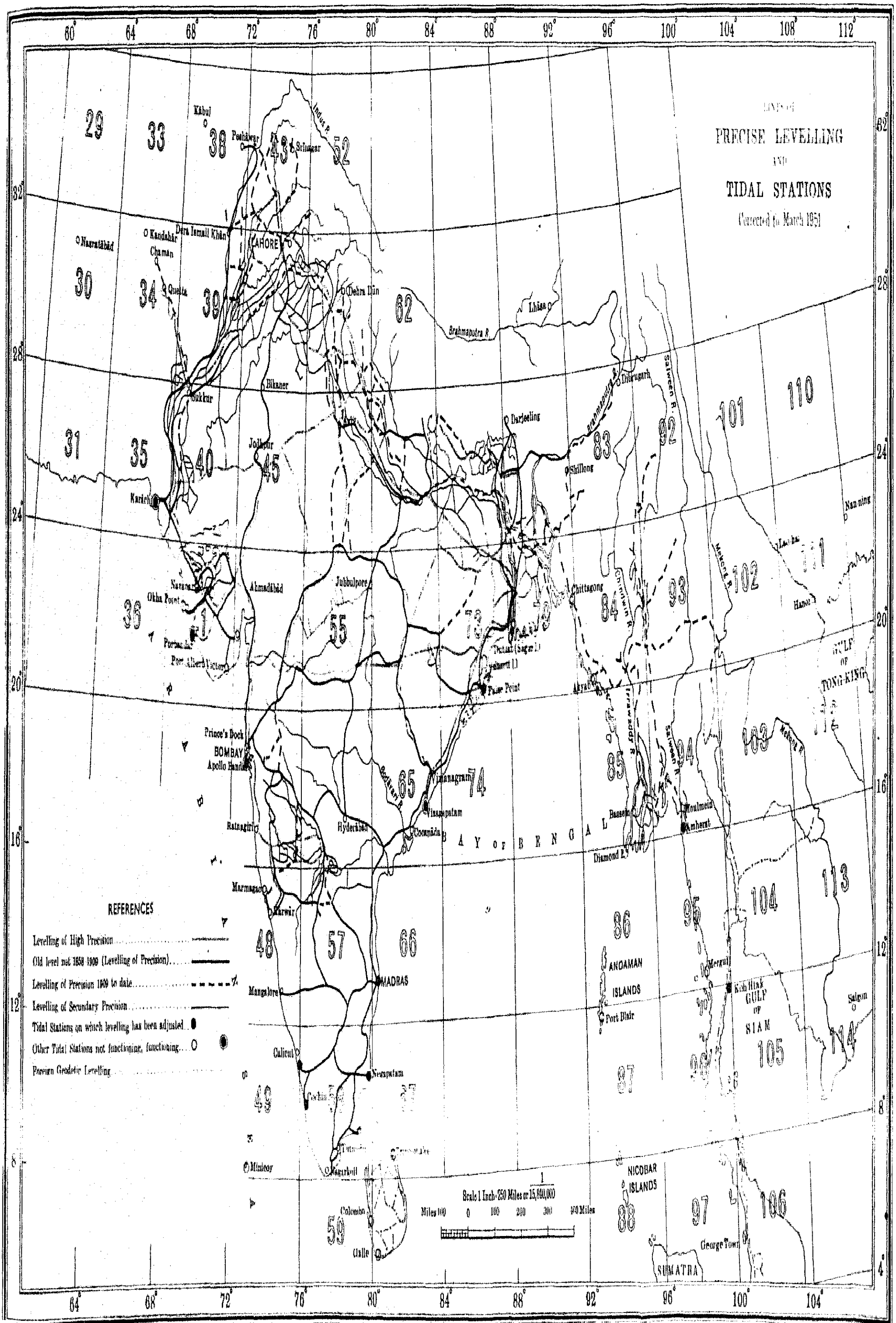
The precision levelling in the Andamans and the tertiary levelling in the Car Nicobar Islands were carried out to provide height control for the large scale maps of these islands, which are being prepared by air photography.

Four secondary levelling detachments were employed in Rājasthān. Their cost was met by the Central Water Power, Irrigation and Navigation Commission. Two detachments carried out secondary levelling in the Jullundur area in connection with the Bhakra Dam Project and were paid for by the Punjab Government.

One secondary levelling detachment under No. 18 Party (Eastern Circle) was employed to determine the mean sea-level heights of the zeroes of four water-gauges erected at the banks of the river Padma (Ganges), which were required by the Indian and Pākistāni Hydrographical Survey Parties working there.

Secondary levelling, carried out in the Gandak area last year, is described in the previous Technical Report. In addition to that, No. 4 Party (Northern Circle) executed three double tertiary levelling lines in this area for additional height control.

Chart IX



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25. Summary of out-turn.—The total out-turn of work carried out during the period under report is as follows :—

(*a*)	High Precision levelling in one direction	141 miles (150 gross)
(*b*)	High Precision levelling in both directions	436 miles (453 gross)
(*c*)	Precision levelling ..	49 miles (55 gross)
(*d*)	Secondary levelling ..	822 miles
(*e*)	Tertiary levelling ..	140 miles

The details are given in Table 1.

26. Kolhāpur to Hubli.—The fore levelling of the portion Kolhāpur to Hubli had been completed in the season 1948–49 by Mr. I. M. Saklani, the route followed being along the old line No. 29, viz., Nira to Hubli. The back levelling was completed this year in two sections. The section Hubli to Belgaum was carried out by Mr. B. P. Rundev (Surveyor) and the section Belgaum to Kolhāpur by Mr. S. Muthukrishnan (Surveyor).

The high precision levelling detachment under Mr. B. P. Rundev with a recorder and 14 *khalāsīs* left Dehra Dūn for the field on 8th October 1950. Work was commenced from B.M. No. 1/48 at Hubli on the 16th October 1950 after the necessary check-levelling. The detachment completed the back levelling up to Belgaum, closing work on B.M. No. 37/48 J on the 17th November 1950, and then proceeded to Kolhāpur to commence work on the Kolhāpur–Raichūr line.

Mr. S. Muthukrishnan assisted by a recorder and 14 *khalāsīs* commenced work from Belgaum on 21st May 1951 and completed the back levelling from Belgaum to Kolhāpur closing work at Kolhāpur on 30th June 1951.

This completed the fore and back levelling between Bombay and Kārwār via Ratnāgiri, Kolhāpur and Hubli. A comparison of the old and new heights of bench-marks from Kolhāpur to Hubli is given in Table 2. The difference between the old and new heights at Hubli is well within the range of levelling error, and consequently Hubli seems to have remained stable with respect to Kolhāpur. There, however, appears to be a slight subsidence at Belgaum. A discussion of the results of levelling of the portion Hubli to Kārwār is given in the last year's report.

The difference of mean sea-level between Bombay and Kārwār obtained by the new levelling is +0·435 feet in a distance of 545 miles. The corresponding difference by the old precision levelling (1878–1909) net is +0·124 feet. These differences are most probably due to errors of levelling.

27. Kolhāpur to Raichūr.—The portion Kolhāpur to Raichūr via Wādi forms part of the line Ratnāgiri to Hyderābād of the new level net of India. As part of this line together with the two branch-lines, viz., Mirāj to Karād and Mamdāpur to Muddebihāl served the purpose of providing height control for the Koyna Irrigation Project, a portion of the cost was paid for by the Bombay Government.

In the past it has been usual to carry out levelling of high precision in the fore direction in one year and in the back direction in the year following. This practice unnecessarily delays the reduction of results for a long time and it was consequently decided to carry out levelling in both the fore and back direction during the same season, taking due precautions to cut out systematic errors. The whole line was divided into sections of about 25 miles each and alternate sections were levelled in the fore direction by different observers, the back levelling of each section being done by the observer other than the one who carried out the fore levelling. Besides the work was so arranged that a period of at least two months elapsed between the fore and back levelling of each section. Two detachments were detailed for the work. The detachment under Mr. B. P. Rundev after completing the back levelling of the Hubli-Belgaum section proceeded to Kolhāpur and commenced work from B.M. No. 23/47 L on 24th November 1950 after the necessary check-levelling. The detachment completed the levelling on the Kolhāpur-Raichūr line and the two branch-lines, Mirāj to Karād and Mamdāpur to Muddebihāl, closing work on B.M. No. 1/56 H at Raichūr on 31st May 1951.

Zeiss Level No. 38870, Model No. III with parallel plate attachment and invar staves Nos. 117 and 118 were used.

The route followed was along metalled roads between Kolhāpur and Athni, between Mirāj and Karād and between Mamdāpur and Jewargi, and along cart-tracks between Athni and Mamdāpur, between Jewargi and Wādi and between Mamdāpur and Muddebihāl. Between Wādi and Raichūr levelling was carried along the railway line.

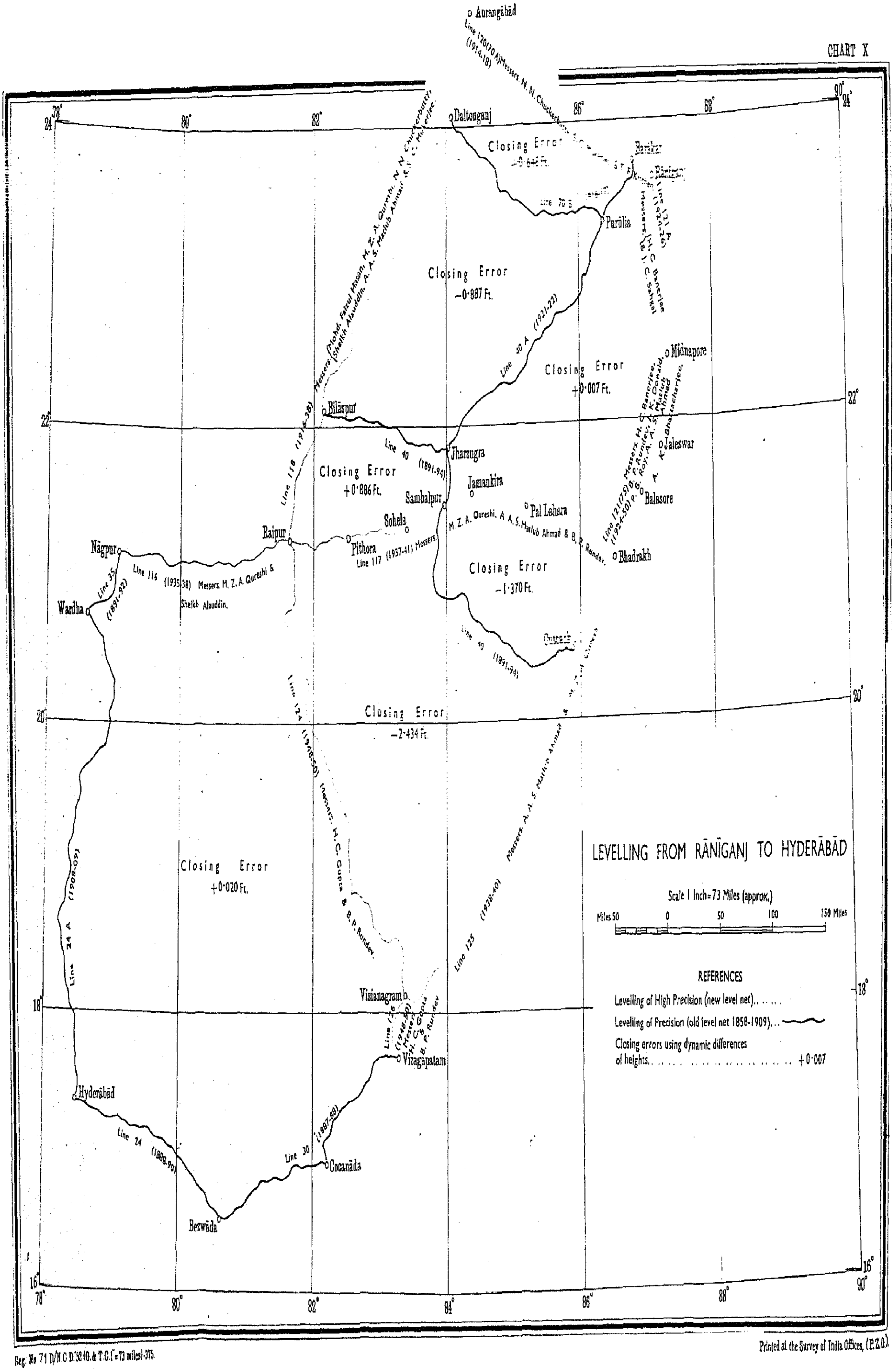
The levelling of these sections in the opposite direction was carried out by Mr. S. Muthukrishnan (Surveyor) assisted by a recorder and 14 *khalāsīs*. He left Dehra Dūn for the field on 8th October 1950 and started work from B.M. No. 14/47 P at Bijāpur on the 16th October 1950 after the necessary check-levelling. The detachment first completed the observations between Muddebihāl and Raichūr via Mamdāpur, Bijāpur, Sindgi, Jewargi, Wādi and Yādgīr, closing work at Yādgīr on 21st January 1951. It then proceeded to Mirāj and completed the observations between Kolhāpur and Mamdāpur and on the branch-line Mirāj to Karād commencing work at Mirāj on 27th January 1951 and closing work at Athni on 15th May 1951. The detachment then proceeded to Belgaum to take up back-levelling from Belgaum to Kolhāpur.

Zeiss level No. 5733, Model No. III with parallel plate attachment and invar staves Nos. 3 and 4 were used.

New type 'M' bench-marks were established at Mirāj, Kavathe Ekand, Shenoli, Karād, Shedbāl, Athni, Sāvalgi, Muddebihāl and Sindgi.

Five triangulation stations, viz., Navalur H.S., Chikk Nandihalligudd H.S., Majala H.S., Kundal H.S. and Athni H.S. of the

CHART X



Reg. No 71 D/N.C.D.'52 (G.& T.C.I"=73 miles)-375.

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Mangalore Meridional Series and two minor stations, viz., Tavadi h.s. and Hulikati h.s. were connected by spirit-levelling.

The country was undulating except for the portion Wādi to Raichūr where the route followed the railway line. It was possible to cross the river Bhima about 10 miles west of Wādi by direct levelling as the water stretch then was only about 150 yards.

Bullock carts were used for transport. The health of the detachment was normal.

Starting with the published height of the S.B.M. at Bombay (B.M. No. 2/47 B), the discrepancies between the new unadjusted heights by high precision levelling and old published heights along the line Bombay–Kolhāpur–Mirāj–Bijāpur–Wādi–Raichūr are as follows :—

(i) At Bijāpur .. .. .. 1·362 ft.
in a distance of 466 miles ;

(ii) At Wādi .. .. .. 1·370 ft.
in a distance of 560 miles ;

(iii) At Raichūr .. .. .. 1·376 ft.
in a distance of 628 miles.

These discrepancies are much greater than the errors of levelling and are possibly due to a gross error of 1 foot somewhere. A revision of the main line from Bombay to Kolhāpur will be undertaken at a suitable opportunity to locate the error.

A number of old bench-marks were connected between Bijāpur and Mamdāpur and between Wādi and Raichūr. Tables 3 and 3(*a*) give the discrepancies between the old and new heights. No change of level is indicated except at Yādgīr, where the old bench-mark was found tilted and apparently disturbed.

28. **Circuit Bhadrakh–Vizianagram–Raipur–Bhadrakh.**—It was mentioned in the last year's report that this circuit has a large closing error of $-2\cdot484$ feet and that this needed investigating. (See Technical Report 1950, Part III, page 24). Chart X shows this circuit and the adjoining circuits, some of which have been formed partly by lines of high precision levelling and partly by precision levelling of the old level net. No definite conclusions can be drawn but it is possible that the high precision line from Raipur to Sambalpur may be seriously in error. This portion will be revised when a suitable opportunity occurs.

29. **Levelling of Precision in the Andamans.**—Levelling in the Andamans has been carried out for the first time this year. A combined river crossing and levelling detachment consisting of Messrs. A. K. Bhattacharjee (Officer Surveyor) and S. K. Bose (Surveyor) with 13 *khalāsīs* was formed to carry out the levelling. The programme was chalked out according to departmental, and the Marine Survey, as well as local P.W.D. requirements.

After necessary arrangements and reconnaissance the work was commenced from the tidal bench-mark* No. C 1898 (Type B) in Ross Island on 3rd December 1950 and closed on 27th April 1951.

* Old Ross bench-mark C mentioned in the preface to Survey of India triangulation pamphlet for the Andamans is reported destroyed. The new Ross bench-mark C is in the Settlement Club and its accepted height above M.S.L. is 8·51 feet.

Crossings over the sea were carried out at the following places :—

(i) Between Ross Island and Aberdeen Jetty, connecting Ross tidal bench-mark C 1898 (Type B) and B.M. No. 1 of 1950 (Rock cut, Type C) near Cellular Jail.	Width 0·75 miles.
(ii) Between Coal Jetty and Chatham Island connecting B.M. 65 (rock-cut) at Coal Jetty and B.M. 73 (rock-cut) at Chatham.	Width 0·55 miles.

The instruments used were T2 Wild Theodolites Nos. 21903 and 17929, rigid stands, special river crossing staves Nos. 01 and 02, Short Base outfit No. 7, H.P. Level No. 50571, invar staves Nos. 119 and 120 and special targets.

The crossings were done by two independent methods—Vertical angle method and double target method, at two sites at each of the two places.

Results are given in Table 5 and are satisfactory.

The crossing at Ross Island–Aberdeen Jetty was a difficult one due to the fact that the observations had to be done in dismal weather and occasional showers, which at times blurred the target on opposite banks.

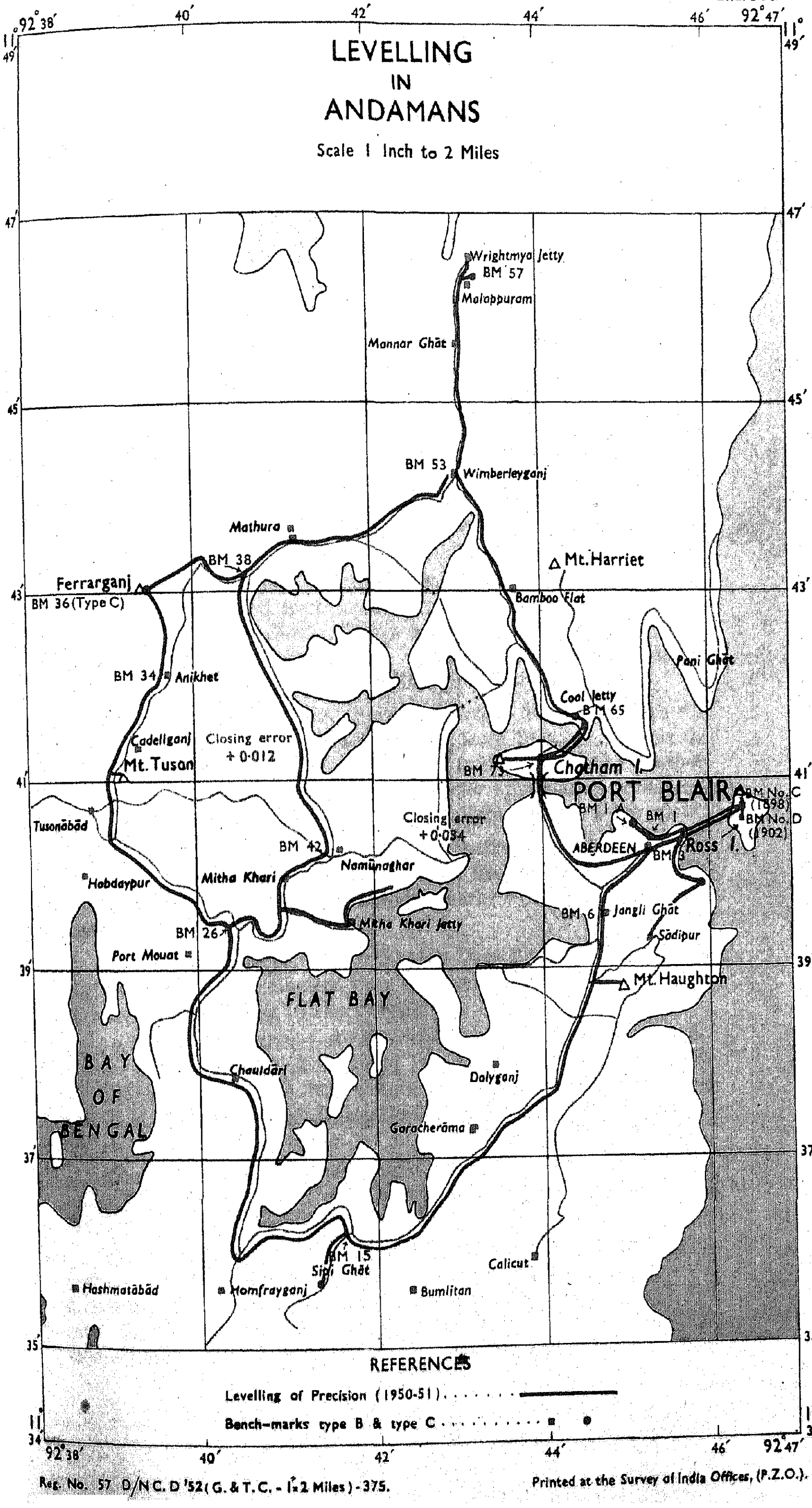
As mentioned above the datum for the levelling in the Andamans is the type 'B' bench-mark No. C in Ross Island. An independent check on the value above M.S.L. of this bench-mark was made available from tidal observations carried out by the Marine Survey at Aberdeen Jetty in February–March 1951, which established M.S.L. at Aberdeen Jetty. This M.S.L. and the old existing M.S.L. at Ross Island, transferred by river crossing observations differed by ·012 feet.

The levelling of precision started from type 'C', G.T.S. B.M. No. 1 of 1950 (rock-cut). This bench-mark is tied to the old tidal bench-marks $\underset{\substack{\text{B.M.}\\ \text{1898}}}{\overset{\text{G.T.S.}}{\square}}$ C and $\underset{\substack{\text{B.M.}\\ \text{1902}}}{\overset{\text{G.T.S.}}{\square}}$ D, which were found intact on Ross Island. The line followed the main road up to B.M. No. 26 near Port Mouat then via Mitha Khari village, Mathura village, Wimberleyganj to Wrightmyo Jetty. A branch-line was run from B.M. No. 26 via Ferrar Ganj, connecting north station of the Andamans geodetic base-line closing on B.M. No. 38 of the main-line.

From B.M. No. 53 a branch-line was carried on to Coal Jetty and connected B.M. 73 in Chatham Island by river-crossing. The levelling from B.M. 73 to B.M. 3 was next carried out which completed the main circuit, see Chart XI.

The closing error of the circuit is +0·046 feet, and has been distributed, each bench-mark receiving a correction proportional to its distance from the starting bench-mark.

Chart XI



Reg. No. 57 D/N C. D '52 (G. & T. C. - 1"=2 Miles) - 375.

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The connection of the datum bench-mark to the zero of the tide-pole at Aberdeen Jetty was also carried out.

All other connections were made by branch-lines including seven triangulation stations and fourteen bench-marks required by the P.W.D. and Marine Survey.

The country was very undulating and hilly, and the roads passed through jungles at places. Suitable camping grounds were scarce and drinking water was not available near the site of work.

For transport only government motor vehicles (land and marine) are available. Rates for motor vehicles inclusive of halting charges are As. -/12/- per mile or Rs. 3/-/- per hour, whichever is higher.

Not more than 10 *khalāsīs* could be obtained for work. No local labour is available and imported labourers from India provided by the local government are not suitable for survey work. The difficulty of labour and transport slowed down the work considerably.

Many of the *khalāsīs* remained sick, the place being malarious. Some of them suffered from general weakness and night blindness due to lack of proper diet. Things were so costly that they could hardly afford to take the normal vegetable diet. Medical help, however, was available from Port Blair Hospital.

Weather remained good except for the first few days of December 1950, when rains and storms were frequent. Towards the end of January 1951 there was slight rain and then the weather was clear up to May 1951. As the summer approached, wells and *nālās* dried up and drinking water was available only at a few spots.

The P.W.D. could not complete the construction of bench-marks in time and, therefore, their connections had to be done after the main lines were completed. Auxiliary marks were left on the main line for this purpose.

30. **Secondary Levelling for Bhakra Dam Project.**—To provide height control for the Bhakra Dam Project two detachments carried out secondary levelling in the Punjab.

(*a*) *Jullundur area.*—A detachment consisting of Mr. R. K. Gupta (Surveyor), Mr. A. K. Sen (Trig. Computer) and 13 *khalāsīs* left Dehra Dūn on the 9th October 1950 and commenced work from B.M. No. 65/44 M at Jullundur City on 16th October 1950 after the necessary check-levelling.

The instruments used were Wild Level No. 21021, Model No. 2 and a pair of Committee pattern wooden staves Nos. 038 A and 038 B.

The system of levelling followed was the same as in previous years, viz., the levelling was carried out both in the fore and back directions by sections of 8 miles, each section being sub-divided into 4 sub-sections of 2 miles each. These sub-sections were levelled first by the fore leveller in the morning and in the afternoon

till the 8-mile section was completed. The back leveller then followed the same procedure of observations for the 8-mile section from the opposite direction levelling in the afternoon the sections done in the morning by the fore leveller and vice versa. This was done to ensure that the same sections were observed under different atmospheric conditions.

The maximum length of shot permissible was 6 chains and the maximum permissible discordance between the middle wire reading and the mean of the three wires readings was 0·003 ft. Two sets were taken at each station by altering the height of the axis of collimation of the instrument, the maximum discrepancy admissible between them being 0·004 ft.

The route followed was along the unmetalled road from Jullundur to Kartārpur along the old line (No. 56 F) and thence towards the south along the metalled road to Sultānpur. From this place the route was along the railway line up to near Malsiān Shāhkot railway station and then along the unmetalled road to Nakodar, where work was closed on 1st December 1950, effecting junction with the second detachment.

The detachment was inspected at Nakodar by Mr. C. B. Madan, Officer Surveyor, from 29th November to 1st December 1950.

A second detachment consisting of Mr. S. N. Nandi (Surveyor), Mr. K. L. Swani (Trig. Computer) and 13 *khalāsīs* left Dehra Dūn on the 9th October 1950 and commenced work from B.M. No. 65/44 M at Jullundur City on 16th October 1950 after the necessary check-levelling.

The instruments used were Wild Level No. 21194, Model No. 2 and Committee pattern wooden staves Nos. 016 A and 016 B.

The levelling was carried out to form a closed circuit from Jullundur City along the metalled road via Nakodar, Phillaur, Nawāshahr and Phagwāra to Jullundur City. After closing work at Jullundur City on 27th December 1950 the detachment proceeded to Siwāni to take up levelling from Siwāni to Delhi.

A new type 'M' bench-mark was established at Kapūrthala, and new type 'B' bench-marks at Sultānpur, Sindhar, Malsiān, Nakodar, Nūrmahal, Nawāshahr, Banga and Jullundur Cantonment. Old embedded bench-marks at Phillaur and Phagwāra were also connected.

Bullock carts were employed for transport in the area. The health of the detachments remained good.

The Jullundur work forms three closed circuits with the old line No. 56 F, see Chart XII. These yield an error of −0·098 feet in 75·3 miles, −0·156 feet in 64·8 miles and +0·131 feet in 49·4 miles respectively.

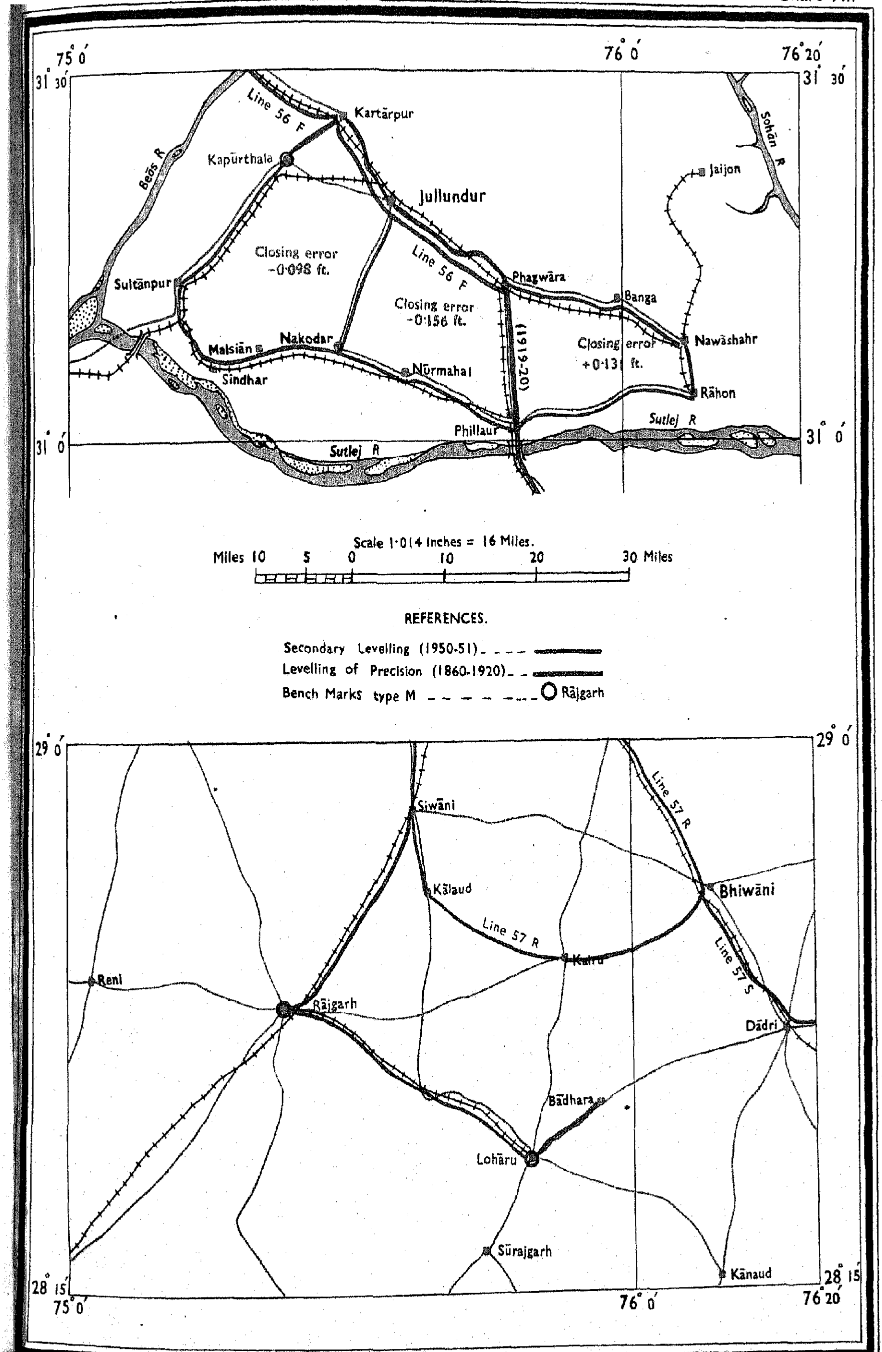
Starting with the published height of B.M. No. 65/44 M at Jullundur City, the 1950–51 height of B.M. No. 89/44 M at Phillaur differs from its published value by −0·226 feet over a distance of 36·6 miles, which is excessive. Check-levelling at Jullundur and Phillaur establishes the stability of bench-marks at these places.

SECONDARY LEVELLING

FOR

BHAKRA DAM PROJECT

Chart XII



Reg. No. 55 D/N.C.D'52(G.& T.C.1·014 Inches=16 Miles)-375.
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The closed circuit of new levelling—Jullundur, Nakodar, Phillaur, Nawāshahr, Phagwāra, Jullundur has a closing error of only $-0 \cdot 025$ feet in 100 miles which is quite satisfactory. It appears then that there has been a regional subsidence of the area around Phillaur since 1920. This is quite likely as this area was badly flooded in 1949–50 and the bench-marks at and near Phillaur are close to the bank of the river Sutlej.

Accepting the published values of the type 'B' bench-marks at Jullundur and Phagwāra, the adjustment has been carried out as follows :—

(i) An error of $-0 \cdot 098$ feet in $75 \cdot 3$ miles has been adjusted in the closed circuit Jullundur–Kartārpur–Kapūrthala–Sultānpur–Nakodar–Jullundur each bench mark receiving a correction proportional to its distance from the starting bench-mark.

(ii) Accepting the height of the new type 'B' at Nakodar deduced from (i), an error of $-0 \cdot 117$ feet in $70 \cdot 6$ miles has been adjusted between Nakodar and Phagwāra.

(iii) An error of $+0 \cdot 072$ feet in a distance of $14 \cdot 4$ miles has been adjusted between Phagwāra and Jullundur.

A number of old bench-marks on the line 56 F were connected. Table 4 gives the discrepancies between the old and new heights.

(*b*) *Line Siwāni to Dādri.*—After closing work at Jullundur City on the 27th December 1950 Mr. S. N. Nandi proceeded to Siwāni to take up the levelling from Siwāni to Dādri. Work was commenced from B.M. No. 25/44 P at Siwāni on the 5th January 1951 after the necessary check-levelling. The levelling was closed at Bādhara near Lohāru on 2nd March 1951, the levelling of the portion Bādhara to Dādri being left over to the next year, when it is also proposed to extend the levelling to Delhi.

The route followed was the railway line up to Lohāru via Rājgarh, thence along camel tracks to Bādhara. The only permanent bench-marks connected were the type 'M' bench-marks at Rājgarh and Lohāru. Type 'B' bench-marks had been planned at intervals of about 5 miles all along the route from Siwāni to Dādri, but their construction was delayed. At least three inscribed bench-marks were left close to the proposed sites of the type 'B' bench-marks. In the coming field season all these type 'B' bench-marks will be connected by levelling to the main line from the inscribed bench-marks left in their vicinity.

The area lies on the fringe of the Rājputāna desert. Camels were employed for transport in the area. Water is difficult to procure.

The health of the detachment was normal.

31. **Rājasthān Levelling.**—Levelling of secondary precision was carried out from Sirsa to Daw via Sūratgarh, Rāmsinghpur and

Sri Mohangarh. The work was divided into four portions as follows :—

(i) From Sūratgarh to Ramsinghpur.

(ii) From Sūratgarh to Sirsa.

(iii) From Ramsinghpur to Sri Mohangarh.

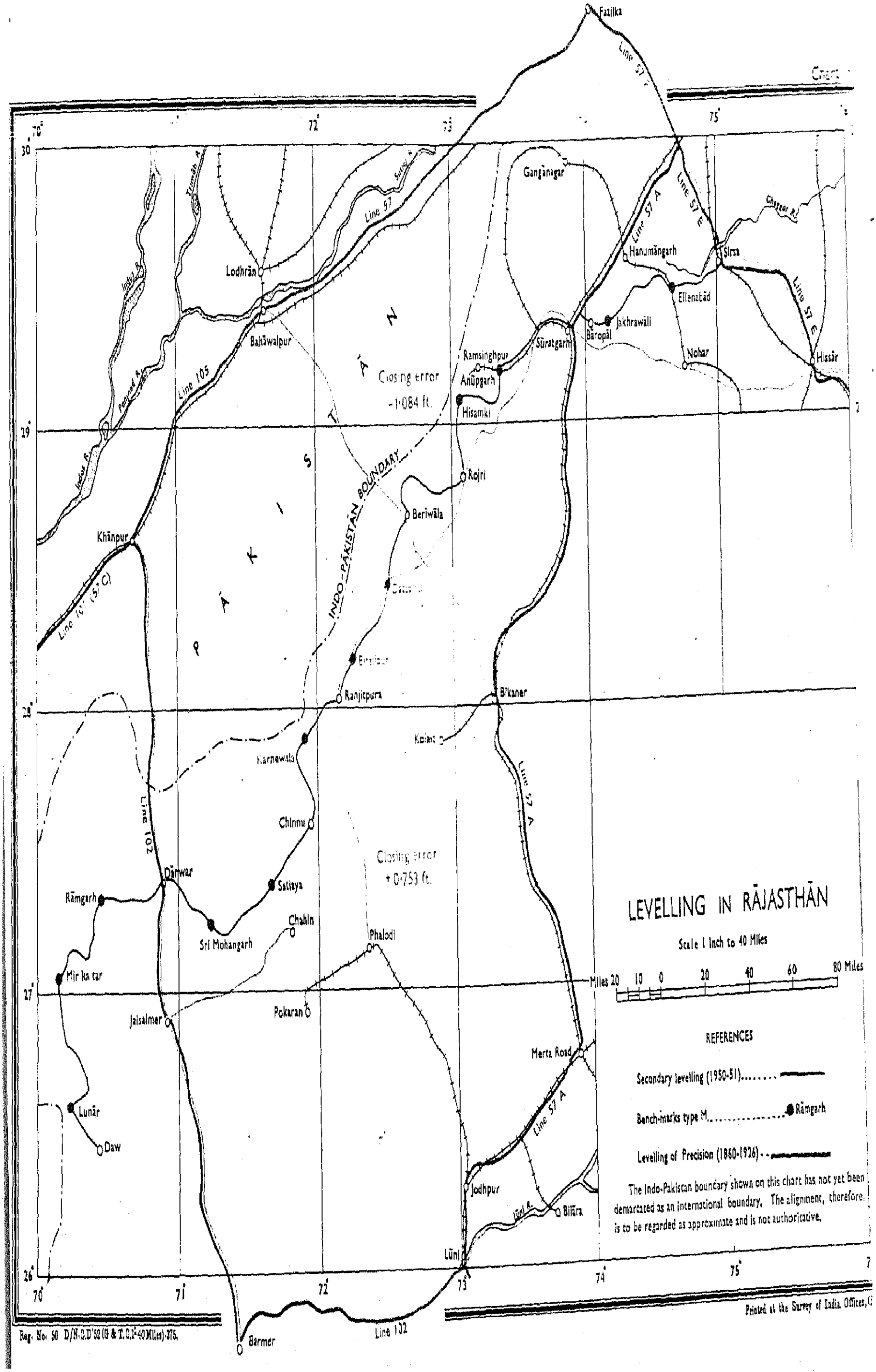
(iv) From Sri Mohangarh to Daw.

The levelling was carried out on the same system as described in para 30.

Stones were embedded at intervals of about a mile along the routes of levelling between Gharsiana and Daw which not only served the purpose of providing sufficient number of inscribed bench-marks but also provided suitable points for the detachments to start and close their day's work.

Four detachments were employed as follows :—

Detachment No.	Levellers	Section	Dates	Length of line
				miles
5	Mr. T. K. Viswanathan, Surveyor Mr. M. M. Sobti, Trig. Computer	(i) From B.M. 15/44 G at Sūratgarh to B.M. 122/44 G at Ramsinghpur	Oct. 10th ~~Nov.~~ 1950 to 13th Nov. 1950	38
	Do.	(ii) From B.M. 15/44 G at Sūratgarh to B.M. 92/44 O at Sirsa (6)	17th Nov. 1950 to 26th Jan. 1951	84
6 and	Mr. Avinash Chandra, Surveyor Mr. K. D. Mehta, Topo. Computer	(iii) From B.M. 122/44 G at Ramsinghpur to B.M. 109/40 M at Sri Mohangarh	17th Oct. 1950 to 26th Feb. 1951	252
8	Mr. J. Narasimhan, Surveyor Mr. R. C. Grover, Topo. Computer			
7	Mr. M. L. Sahdev, Surveyor Mr. V. N. Oberoi, Topo. Computer	(iv) From B.M. 109/40 M at Sri Mohangarh to B.M. 79/40 J at Daw	1st Dec. 1950 to 8th March 1951	151


LEVELLING IN RĀJASTHĀN
Scale 1 Inch to 40 Miles
Miles 20 10 0 20 40 60 80 Miles
REFERENCES
Secondary levelling (1950-51)
Bench-marks type M
Rāmgarh
Levelling of Precision (1860-1926)
The Indo-Pakistan boundary shown on this chart has not yet been demarcated as an international boundary. The alignment, therefore, is to be regarded as approximate and is not authoritative.
PĀKISTĀN
INDO-PĀKISTĀN BOUNDARY
Closing error -1·084 ft.
Closing error +0·753 ft.
Fazilka
Line 57 E
Line 57 A
Line 57
Line 105
Line 102
Line 57 C
Gangānagar
Hanumāngarh
Sirsa
Ellenabād
Jakhrawāli
Baropāl
Nohar
Hissār
Sūratgarh
Ramsinghpur
Anūpgarh
Hisamki
Rojri
Beriwāla
Ranjitpura
Bīkaner
Karnewala
Chinnu
Satiaya
Dānwar
Rāmgarh
Sri Mohangarh
Chahin
Phalodi
Pokaran
Jaisalmer
Mir ka tar
Lunār
Daw
Merta Road
Jodhpur
Bilāra
Lūni
Lūni R.
Barmer
Lodhrān
Bahāwalpur
Khānpur
Indus R.
Panjnad R.
Chenab R.
Sutlej R.
Ghaggar R.
30°
29°
28°
27°
26°
70°
71°
72°
73°
74°
75°
Reg. No. 50 D/N.O.D'52 (G & T.O.)-40 Miles)-375.
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Details regarding the instruments used, the route followed and the mode of transport employed are given below :—

Detachment No.	Section	Level	Staves	Route followed	Mode of transport
5	(i)	Wild Level No. 17783, Model II	Committee pattern wooden staves Nos. 016 A and 016 B	Along the railway line	Bullock carts were were employed.
	(ii)	Do.	Do.	Along the railway line up to Rangmahal Ry. Stn., thence east-wards along camel tracks via Bāropāl, Jakhrawāli, Munda and Shelala villages to Tulwara Jhil Ry. Stn., thence along the railway line to Ellenabād Ry. Stn., and thence along the unmetalled road to Sirsa.	Camels, bullock carts and railways were used.
6 and 8	(iii)	Watts Levels Nos. 58553 and 58585, Model II	Committee pattern wooden staves Nos. 020 A and 020 B and 042 A and 042 B respectively	Along camel tracks via Hisamki, Anandgarh, Dattohar, Birsilpur and Satiaya.	4½-Ton G.M.C. truck was used up to Birsilpur through the kindness of Superintending Engineer, Ferozepore and then camels.
7	(iv)	Watts Level No. 58528, Model II	Committee pattern wooden staves Nos. 022 A and 022 B	Along camel tracks via Rāmgarh, Bandah and Bhuana.	Truck up to Rāmgarh and then camels.

Starting with the published height of the type 'B' bench-mark at Sūratgarh, the 1950–51 height of type 'A' bench-mark at Sirsa differs from its published value by $+0 \cdot 033$ feet over a distance of 84 miles. This error has been adjusted between Sūratgarh and Sirsa each bench-mark receiving a correction proportionate to its distance from the starting bench-mark.

Again, starting with the published height of the type 'B' bench-mark at Sūratgarh the 1950–51 height of the type 'B' bench-mark at Dānwar shows a difference of $-1 \cdot 577$ feet from its published value. This is about twice the limit usually accepted for secondary levelling in this distance. The 1950–51 secondary levelling line from Sūratgarh to Dānwar combined with older levelling forms two closed circuits, see Chart XIII. The closing errors of these

circuits are $-1 \cdot 084$ and $+0 \cdot 753$ feet respectively, indicating that the new levelling is suspect. It is, however, unlikely that the new 1950-51 levelling can be in error by such a large amount and the cause of the discrepancy presumably lies in a local sinkage of the bench-marks round Dānwar. It has, therefore, been decided to adjust the error of $-1 \cdot 577$ feet between Sūṛatgarh and Dānwar.

The line from Dānwar to Daw closes on a new type 'B' bench-mark at Daw and there are no old bench-marks in between. The line is, therefore, pendent.

Health of the detachments was normal. Scarcity of water was the main hardship in the area.

32. **Secondary Levelling for East-West Bengal Boundary.**—The object of the levelling was to determine the heights above M.S.L. of the zeroes of four water-gauges erected at the banks of the river Padma, which were required by the Indian and Pākistāni Hydrographical survey parties working there.

A detachment consisting of Messrs. R. K. Gupta and S. Das Surveyors with 8 *khalāsīs* left Dehra Dūn on the 5th December 1950.

Mr. Mohd. Sadiq Rājpūt, S.A. Supdt., Survey of Pākistān reached Lālgola on 29th December 1950 with 7 Pākistāni *khalāsīs*. The same day Mr. S. Das with 7 Indian *khalāsīs* left Lālgola for Rājshāhi.

The work in India was assigned to a team consisting of Mr. Mohd. Sadiq Rājpūt and Mr. R. K. Gupta as fore and back levellers respectively and 14 *khalāsīs*, 7 from each country. Similarly work in Pākistān was entrusted to Mr. S. Das and Mr. Daud Shāh Sayed, S.A. Supdt., Survey of Pākistān as fore and back levellers with 14 *khalāsīs*, 7 from each country.

The levelling team working in India started work on 30th December 1950. Mr. S. Das who had gone to Pākistān, had to return to India on 9th January 1951 without being able to do any useful work due to Pākistān not being in a position to supply the proper personnel, instruments and equipment necessary for the work. Mr. S. Das, however, on his return to India, started working with Mr. Mohd. Sadiq Rājpūt on 10th January 1951, substituting Mr. R. K. Gupta who was asked to stay with the team as a standby. Work in India was completed on 24th January 1951.

The same team left Lālgola for Rājshāhi on 27th January 1951, starting work in Pākistān on the 31st January 1951 and completing it on 15th February 1951. Mr. S. Das returned to India on 20th February 1951.

Three bench-marks were established within a distance of a quarter of a mile from the water-gauge at Lālgolaghāt, the zero of which was connected by a branch-line emanating from one of them. These three bench-marks, in their turn were connected by a closed circuit of $9 \cdot 75$ miles having a closing error of $-0 \cdot 012$ feet, running from and to the S.B.M. No. 198PP/78 D at Lālgola.

Similarly three bench-marks were established within a distance of about 500 yards of the water-gauge at Chakghāt. One of these was connected to the water-gauge by a branch-line. All the three were again connected by a level line 13·45 miles long with a closing error of +0·012 feet. The line emanated from B.M. No. 78/78 D at Sajanipāra near Nūrpur and closed on B.M. No. 77/78 D (Type B) at Raghunāthganj.

Two bench-marks were established near each of the two water-gauges at Rājshāhi and Mīrganjghāt in Pākistān. They were all connected by one single level line 17·6 miles long with a closing error of +0·011 feet. The line emanated from B.M. No. 100/78 D type 'B' at Baneshwar and closed on B.M. No. 111/78 D at Rājshāhi.

The country was fairly flat and except two cases of river crossing—one in India and another in Pākistān—which were done by direct levelling, there was no difficulty in carrying out the work as it lay mainly along roads.

Motors, motor launches and bullock-carts were used for transport.

The health of the detachment was good.

33. **Tertiary Levelling in Car Nicobars.**—In order to provide height control for mapping the Car Nicobar Islands on scale of 1/25,000, points were required at a density of about ¾ mile. As the country is thickly wooded, clinometric heights were not feasible and recourse was taken to tertiary levelling.

The framework was provided by running a double tertiary line along the periphery coastal road. Four subsidiary circuits were run to check the periphery circuit and provide pegs from which heights were carried to interior points by unconnected levelling lines.

Major C. M. Sahni commenced his levelling on 13th November 1950 from the bench-mark at old Malacca Jetty and connected 11 other bench-marks.

The datum bench-mark at old Malacca Jetty is constructed in the centre of the jetty within about 30 feet from the shore. It is about 280 feet from the sea end of the demolished jetty and about 170 feet from the south end of Akhoojee Boat Shed. It consists of two feet deep square pit filled with cement concrete. In the centre of the mark there is an iron rod ¾ inch thick. The top of the bench-mark is flush with the ground.

When the levelling was completed the datum bench-mark had not been connected to M.S.L. Preliminary observations were made on a tide-pole which was connected by Captain S. Rajendra of I.N.S. *Kukri* to the datum bench-mark. When Major Sahni visited the datum bench-mark on 11th April 1951, he found that some naval rating had dug it up, thinking that the Japanese had buried some treasure there. This bench-mark had consequently to be rebuilt and connected to one old bench-mark, viz., New Malacca Jetty before connecting it to the tide-pole. The result of this connection showed that the heights of all the bench-marks required

a correction of $+0\cdot016$ feet to reduce them to terms of the rebuilt datum.

There is, however, an element of doubt in the height of the datum bench-mark. The results of the connection of this bench-mark to the zero of the tide-pole by Captain Rajendra and Major Sahni differ by 1·683 feet and it is not possible to say where the error lies. The tide-pole was set in an exposed position and had possibly shifted between the two sets of measurement. For the present the value obtained by Major Sahni has been accepted but it is desirable that the datum bench-mark be reconnected to the zero of the tide-pole, and that observations on the tide-pole be taken again for 29 days or a fortnight.

The tidal observations combined with the connection of the datum bench-mark to the zero of the tide-pole by Major Sahni give the height of the rebuilt datum bench-mark above M.S.L. to be 8·913 feet. In terms of this, the heights of the other bench-marks are as follows :—

New Malacca Jetty B.M. ..	8·167 feet
Zulekha house B.M... ..	11·400 ,,
Malacca Henang	11·674 ,,

The instruments used were C.T.S. Level No. 41936, and 14-foot telescopic staves.

34. **Progress of the New Level Net.**—The levelling under report has added 436 miles of complete levelling (both directions) to the total mileage of the new high precision level net.

Out of an estimated total of 15,800 miles the total mileage of this level net completed to date is 12,217 miles.

35. **Connections to M.S.L.**—The completion of the high precision lines from Bombay to Kārwār this field season and from Raipur to Vizagapatam during 1949–50 enables a comparison of the mean sea-levels at these places. The differences of mean sea-levels are tabulated below :—

	Distance	Difference between mean sea-levels
Bombay–Vizagapatam ..	1,190 miles	1·065 feet
Bombay–Kārwār ..	545 ,,	0·435 ,,

36. **Bench-marks.**—During the course of the high precision, precision and secondary levelling the following new bench-marks were built and connected :—

9 Type 'M' bench-marks in Bombay State;

12 Type 'M' and 51 type 'B' bench-marks in the Rājasthān ;

1 Type 'M' and 8 type 'B' bench-marks in Punjāb (India) ; and

2 Type 'M' and 1 type 'B' bench-marks in P.E.P.S.U.

TABLE 1.—*Tabular statement of out-turn of work, season 1950–51*

Detachments and lines levelled	Dates	Distance levelled			Total		Number of stations at which the instruments were set up	Number of bench-marks connected		
		Main-line	Extras and branch-lines*	Total	Rises	Falls		Protected Primary: Rock-out	Protected Primary: Others	Others
		Mls.	*Mls.*	*Mls.*	*feet*	*feet*				
H.P. Levelling Detachment.										
Line No. 127 (Ratnāgiri to Hyderābād) portion Kolhāpur to Wādi and Line No. 130 (Wādi to Bangalore) portion Wādi to Raichūr (Fore)	24–11–50 to 28–5–51	305	148	453	12,358	11,509	6,851	1	14	630
Do. (Back)	16–10–50 to 17–11–50	305	145	450	11,638	12,487	6,890	1	14	630
Line No. 129 (Kolhāpur to Mangalore) portions (*a*) Hubli to Belgaum (Back)	16–10–50 to 17–11–50	64	9	73	3,302	2,835	2,086	..	13	85
(*b*) Belgaum to Kolhāpur (Back)	21–5–51 to 30–6–51	70	7	77	3,106	3,721	1,388	1	13	114
Precision Levelling Detachment.										
Line Port Blair to Wrightmyo Jetty	11–12–50 to 12–3–51	33	22	55	3,714	2,761	1,250	9	4	96
Secondary Levelling Detachment.										
Line Jullundur City to Nakodar (via Kapūrthala)	16–10–50 to 1–12–50	60	14	74	369	395	811	..	3	74
Line Jullundur City to Jullundur City (via Phillaur, Rāhon)	16–10–50 to 27–12–50	100	36	136	603	599	1,040	..	7	107
Line Siwāni to Delhi portion Siwāni–Bādhara	5–1–51 to 1–3–51	69	28	97	831	691	2,080	..	3	93

* This column includes check-levelling and relevelments also.

(*Continued*)

TABLE 1.—*Tabular statement of out-turn of work, season 1950–51*—(concld.)

Detachments and lines levelled	Dates	Distance levelled: Main-line	Distance levelled: Extras and branch-lines*	Distance levelled: Total	Total: Rises	Total: Falls	Number of stations at which the instruments were set up	Number of bench-marks connected: Protected Primary: Rock-cut	Number of bench-marks connected: Protected Primary: Others	Number of bench-marks connected: Others
		Mls.	*Mls.*	*Mls.*	*feet*	*feet*				
Secondary Levelling Detachment.										
Line Sūratgarh to Sirsa	17–11–50 to 23–1–51	84	23	107	598	498	1,010	..	9	87
Line Sūratgarh to Daw (*a*) portion Sūratgarh to Rāmsinghpur	10–10–50 to 13–11–50	38	13	51	121	157	473	..	9	64
(*b*) portion Rāmsinghpur to Sri Mohangarh	17–10–50 to 26–2–51	252	60	312	5,310	5,264	4,133	..	34	224
(*c*) portion Sri Mohangarh to Daw	1–12–50 to 8–3–51	151	27	178	3,109	3,144	2,339	..	20	131
Lālgola P.S. to Lālgola P.S. via water-gauge at Lālgolāghat (Fore)	30–12–50 to 10–1–51	10	1	11	95	63	162	..	2	13
Do. (Back)	Do.	10	1	11	97	64	154	..	2	13
Nūrpur to Jangipur via water-gauge at Chakghāt (Fore)	12–1–51 to 24–1–51	13	10	23	255	252	309	..	2	14
Do. (Back)	Do.	13	1	14	163	164	205	..	2	14
Baneshwar to Rājshāhi via water-gauge at Mirganjghāt and Rājshāhi (Fore)	1–1–51 to 2–1–51 6–1–51 to 7–1–51 27–1–51 to 15–2–51	49	9	58	194	250	334	..	12	18
Do. (Back)	27–1–51 to 15–2–51	49	6	55	158	210	267	..	12	14

* This column includes check-levelling and relevelments also.

TABLE 2.—*Old and new (1950–51) levelling from Kolhāpur to Hubli*

B.M. Nos.	Brief description	Distance from B.M. No. 23/47 L	Date of original levelling	Observed height above (+) or below (–) B.M. No. 23/47 L		Discrepancy (New–Old)
				Old	New	
		Miles		*feet*	*feet*	*feet*
23/47 L	E.B.M. at Kolhāpur ..	0·00	1877–79	0·000	0·000	0·000
31/47 L	E.B.M. at Kāgal..	11·05	„	– 16·694	– 16·155	+0·539
32/47 L	Step ..	11·08	„	– 17·904	– 18·027	–0·123
41/47 L	Bridge ..	20·86	„	– 56·819	– 57·064	–0·245
44/47 L	Step ..	24·90	„	+ 126·131	+ 125·933	–0·198
45/47 L	E.B.M. at Nipāni..	25·24	„	+ 128·370	+ 128·166	–0·204
50/47 L	Bridge ..	32·55	„	+ 381·007	+ 380·945	–0·062
54/47 L	Bridge ..	35·55	„	+ 371·582	+ 372·586	+1·004
58/47 L	Bridge ..	39·70	„	+ 230·628	+ 230·409	–0·219
60/47 L	E.B.M. at Gotūr ..	41·25	„	+ 270·308	+ 270·089	–0·219
63/47 L	Bridge ..	41·75	„	+ 218·831	+ 218·575	–0·256
64/47 L	Bridge ..	44·09	„	+ 206·320	+ 206·036	–0·284
65/47 L	E.B.M. at Hattargi	48·30	„	+ 356·001	+ 355·749	–0·252
66/47 L	Bridge ..	48·36	„	+ 355·551	+ 355·337	–0·214
68/47 L	Bridge ..	52·58	„	+ 311·368	+ 311·625	+0·257
69/47 L	E.B.M. at Sutkatte	53·19	„	+ 373·589	+ 373·303	–0·286
71/47 L	Culvert ..	55·40	„	+ 566·685	+ 566·481	–0·204
31/48 I	E.B.M. at Kākti ..	64·16	„	+ 583·144	+ 582·702	–0·442
40/48 I	E.B.M. at Belgaum	69·78	„	+ 623·416	+ 623·172	–0·244
37/48 I	S.B.M. at Belgaum	70·22	„	+ 673·313	+ 673·018	–0·295
32/48 I	Flooring ..	70·96	„	+ 599·984	+ 599·678	–0·306
34/48 I	Parapet ..	72·24	„	+ 603·389	+ 603·807	+0·418
44/48 I	Bridge ..	84·63	„	+ 360·005	+ 359·892	–0·113
45/48 I	E.B.M. at Bāgevādi	84·64	„	+351·360	+ 351·328	–0·032
46/48 I	E.B.M. at Mugut-Khān Hubli ..	89·51	„	+ 314·300	+ 314·165	–0·135
52/48 I	Culvert ..	97·91	„	+ 488·545	+ 488·508	–0·037
54/48 I	E.B.M. at Kittūr..	100·61	„	+ 561·828	+ 561·835	+0·007
59/48 I	E.B.M. at Mommigatti ..	114·50	„	+ 451·812	+ 451·689	–0·123
53/48 I	E.B.M. at Dhārwār ..	119·81	„	+ 535·091	+ 535·110	+0·019
1/48 M	E.B.M. at Hubli ..	133·25	„	+ 210·376	+ 210·112	–0·264
2/48 M	Parapet ..	133·45	„	+ 225·918	+ 225·618	–0·300
3/48 M	Flooring ..	133·52	„	+ 228·541	+ 228·272	–0·269

TABLE 3.—*Old and new (1950–51) levelling from Wādi to Raichūr*

B.M. Nos.	Brief description	Distance from B.M. No. 83/56 C	Date of original levelling	Observed height above (+) or below (−) B.M. No. 83/56 C		Dis-crepancy (New−Old)
				Old	New	
		Miles		*feet*	*feet*	*feet*
83/56 C	Type B at Wādi ..	0·00	1906–08	0·000	0·000	0·000
15/56 H	Bridge ..	4·40	„	− 93·756	− 93·756	0·000
18/56 H	Culvert ..	6·93	„	− 74·370	− 74·365	+0·005
22/56 H	E.B.M. at Nālwār	8·50	„	− 78·741	− 78·773	−0·032
19/56 H	Bridge ..	8·55	„	− 75·302	− 75·280	+0·022
23/56 H	Stone coping ..	10·17	„	− 71·392	− 71·389	+0·003
24/56 H	Culvert ..	12·66	„	− 58·025	− 58·010	+0·015
25/56 H	Culvert ..	14·66	„	− 101·588	− 101·570	+0·018
26/56 H	Culvert ..	16·39	„	− 146·130	− 146·103	+0·027
27/56 H	Culvert ..	19·70	„	− 153·570	− 153·568	+0·002
28/56 H	Culvert ..	21·05	„	− 166·154	− 166·146	+0·008
29/56 H	Culvert ..	23·24	„	− 204·900	− 204·889	+0·011
31/56 H	Bridge ..	23·39	„	− 209·433	− 209·426	+0·007
32/56 H	E.B.M. at Yādgīr	24·60	„	− 204·836	− 205·054	−0·218
33/56 H	Stone coping ..	24·59	„	− 201·653	− 201·601	+0·052
34/56 H	Stone flooring ..	24·56	„	− 201·275	− 201·365	+0·090
35/56 H	Stone coping ..	24·48	„	− 201·742	− 201·573	+0·169
36/56 H	Bridge ..	25·26	„	− 202·104	− 202·080	+0·024
37/56 H	Bridge ..	26·74	„	− 202·909	− 202·832	+0·077
38/56 H	Culvert ..	28·14	„	− 204·618	− 204·565	+0·053
39/56 H	Culvert ..	29·69	„	− 202·522	− 202·474	+0·048
40/56 H	Bridge ..	31·66	„	− 191·652	− 191·605	+0·047
41/56 H	Culvert ..	33·42	„	− 195·123	− 195·075	+0·048
42/56 H	Culvert ..	35·14	„	− 194·560	− 194·525	+0·035
43/56 H	Culvert ..	36·05	„	− 174·739	− 174·744	−0·005
44/56 H	Bridge ..	37·95	„	− 180·787	− 180·801	−0·014
45/56 H	Type B at Nārāyan-pet road R.S. (Saidāpur) ..	39·18	„	− 173·858	− 173·838	+0·020
46/56 H	Stone coping ..	39·20	„	− 171·323	− 171·336	−0·013
48/56 H	Culvert ..	40·46	„	− 193·109	− 193·073	+0·036
49/56 H	Bridge ..	42·53	„	− 220·955	− 220·874	+0·081
50/56 H	Culvert ..	44·45	„	− 227·834	− 227·811	+0·023
51/56 H	Culvert ..	46·44	„	− 189·890	− 189·873	+0·017
52/56 H	Culvert ..	48·44	„	− 223·097	− 223·075	+0·022
57/56 H	Stone coping ..	51·79	„	− 261·806	− 261·774	+0·032
54/56 H	Stone step ..	51·84	„	− 263·533	− 263·516	+0·017
59/56 H	Bridge ..	52·40	„	− 256·641	− 256·675	−0·034

(*Continued*)

TABLE 3.—*Old and new (1950–51) levelling from Wādi to Raichūr*—(concld.)

B.M. Nos.	Brief description	Distance from B.M. No. 83/56 C	Date of original levelling	Observed height above (+) or below (−) B.M. No. 83/56 C		Dis-crepancy (New–Old)
				Old	New	
		Miles		*feet*	*feet*	*feet*
60/56 H	Bridge ..	53·16	1906–08	− 256·654	− 256·663	−0·009
61/56 H	Bridge ..	54·05	,,	− 267·799	− 267·825	−0·026
63/56 H	Stone coping ..	57·42	,,	− 227·271	− 227·228	+0·043
64/56 H	Type 'B' at Chiksugūr R.S. ..	57·44	,,	− 229·300	− 229·285	+0·015
65/56 H	Stone coping ..	57·46	,,	− 227·601	− 227·662	−0·061
66/56 H	Bridge ..	58·51	,,	− 258·683	− 258·633	+0·050
67/56 H	Culvert ..	61·70	,,	− 179·074	− 179·012	+0·062
68/56 H	Culvert ..	62·08	,,	− 170·048	− 170·001	+0·047
69/56 H	Culvert ..	62·15	,,	− 168·877	− 168·891	−0·014
70/56 H	Bridge ..	64·58	,,	− 133·162	− 133·110	+0·052
2/56 H	Bridge ..	66·08	,,	− 113·277	− 113·258	+0·019
73/56 H	Flooring ..	66·65	,,	− 68·183	− 68·167	+0·016
74/56 H	S.B.M. at Raichūr	66·76	,,	− 84·867	− 84·843	+0·024
72/56 H	Stone flooring ..	66·86	,,	− 68·268	− 68·249	+0·019
105/56 H	Culvert ..	66·68	,,	− 109·495	− 109·655	−0·160
1/56 H	E.B.M. at Raichūr	67·62	,,	− 89·886	− 89·823	+0·063
3/56 H	Stone coping ..	67·76	,,	− 85·538	− 85·494	+0·044

TABLE 3(*a*).—*Old and new (1950–51) levelling from Bijāpur to Mulvād*

B.M. Nos.	Brief description	Distance from B.M. No. 14PP/47 P	Date of original levelling	Observed height above (+) or below (−) B.M. No. 14PP/47 P		Dis-crepancy (New–Old)
				Old	New	
		Miles		*feet*	*feet*	*feet*
14PP/47P	Type 'P' at Bijāpur	0·00	1914–15	0·000	0·000	0·000
125/47P	Stone step ..	0·91	,,	+ 4·753	+ 4·757	+ ·004
124/47P	Stone flooring ..	0·92	,,	+ 9·614	+ 9·615	+ ·001
12/47P	Stone ..	0·31	,,	+ 12·696	+ 12·686	− ·010
13/47P	Step ..	0·72	,,	+ 15·913	+ 15·908	− ·005
19/47P	Stone flooring ..	0·99	,,	+ 17·260	+ 17·249	− ·011
226/47P	Type 'B' near Jumnāl village ..	7·15	,,	+ 78·328	+ 78·297	− ·031
221/47P	Type 'B' at Mulvād	16·01	,,	+ 109·186	+ 109·146	− ·040
220/47P	Bridge ..	16·19	,,	+ 108·886	+ 108·836	− ·050

TABLE 4.—*Check-levelling*

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign −, less in 1950-51 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1950–51	
			miles		*feet*	*feet*	*feet*
			At Raichūr on line No. 22				
74	56 H	S.B.M. at Raichūr..	0·00	1906–08	0·000	0·000	0·000
72	,,	Stone flooring ..	0·10	,,	+ 16·599	+ 16·594	−0·005
73	,,	Stone flooring ..	0·10	,,	+ 16·684	+ 16·676	−0·008
2	,,	Bridge ..	0·58	,,	− 28·410	− 28·415	−0·005
105	,,	Culvert ..	0·93	,,	− 24·628	− 24·812	−0·184
1	,,	Type 'B' at Raichūr	1·88	,,	− 5·019	− 4·980	+0·039
3	,,	Stone coping ..	2·00	,,	− 0·671	− 0·651	+0·020
70	,,	Bridge ..	2·19	,,	− 48·295	− 48·267	+0·028
			At Wādi on line No. 22				
83	56 C	E.B.M. at Wādi ..	0·00	1906–08	0·000	0·000	0·000
84	,,	Stone coping ..	0·02	,,	+ 5·285	+ 5·250	−0·035
85	,,	Stone coping ..	0·08	,,	+ 5·295	+ 5·340	+0·045
86	,,	Stone coping ..	0·19	,,	+ 5·292	+ 4·621	−0·671
			At Bijāpur on line No. 26 B				
14PP	47 P	Type 'P' at Bijāpur	0·00	1921–22	0·000	0·000	0·000
12	,,	Flooring ..	0·31	,,	+ 12·703	+ 12·686	−0·017
13	,,	Step ..	0·71	,,	+ 15·915	+ 15·908	−0·007
19	,,	Flooring ..	0·94	,,	+ 17·261	+ 17·249	−0·012
125	,,	Step ..	0·95	,,	+ 4·753	+ 4·758	+0·005
124	,,	Stone flooring ..	0·95	,,	+ 9·613	+ 9·616	+0·003
			At Sūratgarh on line No. 57 A				
15	44 G	Type 'B' at Sūratgarh ..	0·00	1907–08	0·000	0·000	0·000
16	,,	Masonry block ..	1·00	,,	+ 8·663	+ 8·656	−0·007
17	,,	Masonry block ..	3·00	,,	+ 17·025	+ 16·987	−0·038
18	,,	Masonry block ..	5·00	,,	+ 25·734	+ 25·673	−0·061
12	,,	Abutment of bridge	0·50	,,	+ 3·211	+ 3·555	+0·344
11	,,	Masonry block ..	1·20	,,	+ 0·702	+ 0·721	+0·019
8	,,	Masonry block ..	5·20	,,	+ 8·384	+ 8·378	−0·006
7	,,	Type 'B' at Rangmahal ..	5·70	,,	+ 5·888	+ 5·866	−0·022

(*Continued*)

TABLE 4.—*Check-levelling.*—(contd.)

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected for check-levelling			Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark as determined by			Difference (check − original). The sign + denotes that the height was greater and the sign −, less in 1950–51 than when originally levelled
No.	Degree sheet	Description		Date of original levelling	Original levelling	Check-levelling 1950–51	
			miles		*feet*	*feet*	*feet*
		At Dānwar on line No. 102					
6	40 I	Type 'B' at Dānwar	0·00	1921–25	0·000	0·000	0·000
7	,,	Well ..	5·81	,,	+ 75·263	+ 75·191	−0·072
8	,,	Parapet ..	7·45	,,	+ 70·400	+ 70·317	−0·083
		At Jullundur City on line No. 56 F					
65	44 M	Type 'B' at Jullundur City ..	0·00	1919–20	0·000	0·000	0·000
68	,,	Flooring ..	0·98	,,	+ 0·272	+ 0·257	−0·015
69	,,	Block of stone ..	2·39	,,	− 1·648	− 2·210	−0·562
70	,,	Parapet ..	2·50	,,	− 0·251	− 0·341	−0·090
72	,,	Step ..	3·89	,,	+ 3·148	+ 2·910	−0·238
75	,,	Bridge ..	8·83	,,	− 12·837	− 13·263	−0·426
76	,,	Bridge ..	9·98	,,	− 1·201	− 1·263	−0·062
77	,,	Step ..	12·50	,,	+ 12·285	+ 12·234	−0·051
78	,,	Parapet ..	13·75	,,	+ 14·628	+ 14·561	−0·067
79	,,	Type 'B' at Phagwāra ..	14·23	,,	+ 13·743	+ 13·680	−0·063
80	,,	Wall of water-tank	14·94	,,	+ 19·744	+ 19·679	−0·065
81	,,	Railway culvert ..	15·17	,,	+ 17·483	+ 17·296	−0·187
58	,,	Cattle trough ..	7·53	,,	− 2·371	− 2·345	+0·026
57	,,	Brick flooring ..	9·62	,,	− 7·460	− 7·440	+0·020
		At Phillaur on line No. 56 F					
89	44 M	Type 'B' at Phillaur	0·00	1919–20	0·000	0·000	0·000
88	,,	Curb of well ..	0·48	,,	+ 6·524	+ 6·540	+0·016
87	,,	Wall of cattle trough	1·34	,,	+ 4·730	+ 4·748	+0·018
86	,,	Block of stone ..	4·13	,,	+ 0·516	+ 0·523	+0·007
		At Sirsa on line No. 57 Q					
92/(6)	44 O	Type 'A' at Sirsa ..	0·00	1930–31	0·000	0·000	0·000
5	,,	Platform ..	0·46	,,	+ 5·279	+ 5·297	+0·018
4	,,	Stone ..	0·80	,,	+ 4·073	+ 4·086	+0·013
3	,,	Parapet ..	1·49	,,	+ 8·319	+ 9·125	+0·806
91	,,	Veranda ..	0·04	,,	+ 3·112	+ 3·136	+0·024
90	,,	Platform ..	0·55	,,	+ 8·912	+ 9·077	+0·165
87	,,	Parapet ..	1·84	,,	+ 5·918	+ 5·866	−0·052
156	44 K	Milestone ..	3·86	,,	+ 3·350	+ 2·879	−0·471
153	,,	Milestone ..	6·78	,,	+ 1·522	+ 1·668	+0·146
150	,,	Pier ..	9·33	,,	+ 1·581	+ 1·597	+0·016
149	,,	Pier ..	9·43	,,	+ 1·974	+ 1·988	+0·014
147	,,	Type 'B' at Otu ..	9·74	,,	− 6·548	− 6·529	+0·019

(*Continued*)

TABLE 4.—*Check-levelling.*—(concld.)

Discrepancies between the old and new heights of bench-marks.

Bench-marks of the original levelling that were connected for check-levelling: No.	Degree sheet	Description	Distance from starting bench-mark	Observed height above (+) or below (−) starting bench-mark as determined by: Date of original levelling	Original levelling	Check-levelling 1950–51	Difference (check − original). The sign + denotes that the height was greater and the sign −, less in 1950–51 than when originally levelled.
			miles		*feet*	*feet*	*feet*
			At Lālgola on line No. 151				
198PP	78 D	S.B.M. at Lālgola ..	0·0	1925–26	0·000	0·000	0·000
196	,,	Kyanite-granulite prism ..	0·0	,,	− 0·680	− 0·679	+0·001
195	,,	Kyanite-granulite prism ..	0·0	,,	− 0·689	− 0·689	0·000
200	,,	Well ..	0·1	,,	+ 0·227	+ 0·112	−0·115
259	,,	Inspection bungalow compound ..	0·1	,,	− 3·787	− 3·781	+0·006
57	,,	Veranda ..	0·2	,,	+ 0·862	+ 0·793	−0·069
194	,,	Step ..	0·2	,,	+ 2·462	+ 2·401	−0·061
			At Nūrpur on line No. 77 M				
83	78 D	Block of stone ..	0·0	1920–21	0·000	0·000	0·000
82	,,	Block of stone ..	1·3	,,	+ 1·532	+ 1·489	−0·043
79	,,	Block of stone ..	3·0	,,	− 0·811	− 0·791	+0·020
78	,,	Block of stone ..	5·0	,,	+ 0·640	+ 0·641	+0·001
81	,,	Nūrpur indigo factory ..	6·6	,,	− 1·453	− 1·498	−0·045
			At Jangipur on line No. 77 M				
77	78 D	At Jangipur S.D.O.'s court ..	0·0	1920–21	0·000	0·000	0·000
76	,,	Step ..	0·0	,,	+ 4·233	+ 4·266	+0·033
75	,,	Culvert ..	0·3	,,	+ 4·341	+ 4·403	+0·062
73	,,	Block of stone ..	1·0	,,	+ 0·373	+ 0·361	−0·012
163	,,	Stone ..	2·4	,,	+ 12·983	+ 13·168	+0·185
72	,,	Block of stone ..	2·6	,,	− 2·503	− 2·506	−0·003
			At Baneshwar on line No. 77 N				
100	78 D	At Baneshwar madrasa ..	0·0	1920–21	0·000	0·000	0·000
99	,,	Culvert ..	1·6	,,	+ 6·045	+ 6·045	0·000
101	,,	Bridge ..	1·6	,,	+ 6·089	+ 6·143	+0·054
102	,,	Bridge ..	2·2	,,	+ 7·591	+ 7·527	−0·064
103	,,	Bridge ..	3·9	,,	+ 13·078	+ 13·103	+0·025
104	,,	Bridge ..	5·2	,,	+ 14·986	+ 14·875	−0·111

TABLE 5.—*Results of Crossings, Andamans*

River Crossed	Difference of height		Difference of heights				Mean value	Final value accepted for computation	Span of the river	
			Vertical Angle		Double target					
	From	To	Site I	Site II	Site I	Site II			Site I	Site II
			Observers :—M/s. A. K. Bhattacharjee and S. K. Bose							
			feet	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*	*feet*
Ross Island and Aberdeen Jetty	B.M. No. C. (Type 'B') at Ross Island	B.M. No. 1 (Type 'C') at Main Island	+ 18·258	+ 18·248	+ 18·227	+ 18·227	+18·240	+18·240	3957	3986
Panighāt (Coal Jetty) and Chatham Island	B.M. No. 65 rock-cut	B.M. No. 73 rock-cut	+ 4·379	+ 4·387	+ 4·385	+ 4·394	+4·386	+ 4·386	2851	2976

TABLE 6.—*List of triangulation stations connected by spirit-levelling, season 1950–51*

Degree Sheet No.	Name of station	Height above mean sea-level		Difference (Lev.—Trian.)	REMARKS
		Spirit-levelling	Triangulation		
		feet	*feet*	*feet*	
44 G	Sūratgarh s. Lat. 29° 19′ 37″·65 Long. 73 54 3·77	601·603	Not available	..	On turret of fort.
44 D	Karamala H.S. Lat. 28° 45′ 6″·50 Long. 72 45 39·40	545	551	− 6	Upper mark-stone.
47 P	Athni H.S. Lat. 16° 42′ 51″·64 Long. 75 06 26·27	2049	2048	+ 1	S.L. height refers to the base of the referring pillar protecting the top-most mark on the upper surface of circular pillar. Trig. height refers to the upper surface of circular pillar.
47 K	Kundal H.S. Lat. 17° 07′ 30″·24 Long. 74 24 3·10	2685	2679	+ 6	S.L. height refers to the top of the protecting pillar which is 0·25 feet above the top surface of circular pillar. Trig. height refers to the top surface of circular pillar.
47 L	Majala M.S. Lat. 16° 46′ 56″·82 Long. 74 26 55·57	2614	2613	+ 1	S.L. height refers to the upper surface of circular pillar. Trig. height also refers to the same point.

(Continued)

TABLE 6.—*List of triangulation stations connected by spirit-levelling, season 1950–51*—(concld.)

Degree Sheet No.	Name of station	Height above mean sea-level: Spirit-levelling	Height above mean sea-level: Triangulation	Difference (Lev.—Trian.)	REMARKS
		feet	*feet*	*feet*	
48 I	Chikk Nandihalligudd H.S. Lat. 15° 37′ 56″·39 Long. 74 49 1·46	2604	2601	+ 3	S.L. height refers to the lower-mark. Trig. height originally refers to the upper surface of the circular pillar but is reduced to refer the lower-mark.
48 M	Navalur H.S. Lat. 15° 25′ 31″·17 Long. 75 03 15·42	2451	2445	+ 6	S.L. height refers to the upper surface of the circular pillar and not the upper surface of protecting pillar which is built to protect the upper mark on the top of circular pillar. Trig. height refers to the upper surface of circular pillar.
48 I	Honodip h.s. * Lat. 15° 38′ 20″ Long. 74 45 02	2466	2465*	+ 1	Upper-mark.
47 L	Taundi h.s. * Lat. 16° 21′ 1″ Long. 74 24 24	2661	2650*	+11	Upper-mark.
86 A	Haughton H.S. Lat. 11° 38′ 50″·03 Long. 92 44 56·38	510	511	— 1	Upper-mark.
86 A	Tusan H.S. Lat. 11° 41′ 02″·85 Long. 92 39 08·88	601	601	0	Upper-mark.

* Co-ordinates and heights taken from map hence approximate.

CHAPTER IV

TIDES

BY B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

37. **Tidal Observations.**—(*a*) *By port authorities.*—Automatic tidal registrations were continued at Aden, Karāchi*, Bombay (Apollo Bandar) and Calcutta (Garden Reach) with the Survey of India gauges, and at Vizagapatam, Saugor, Gangra, Balari and Diamond Harbour with the port's own instruments. Also, systematic half-hourly tide-pole readings were continued at Kandla port, while daylight observations of high and low waters were continued at Bhāvnagar, Chittagong* and Rangoon, as before.

A standard automatic tide-gauge of the U.S.A. pattern (purchased recently by the Survey of India) was installed at Kandla on 16th October 1950, and has since been in operation. A brief description of the tidal observatory is given at the end of this Chapter (page 56).

There have been no serious breaks in the automatic registrations at any of these above ports. A few temporary stoppages that occurred at some places are detailed below :—

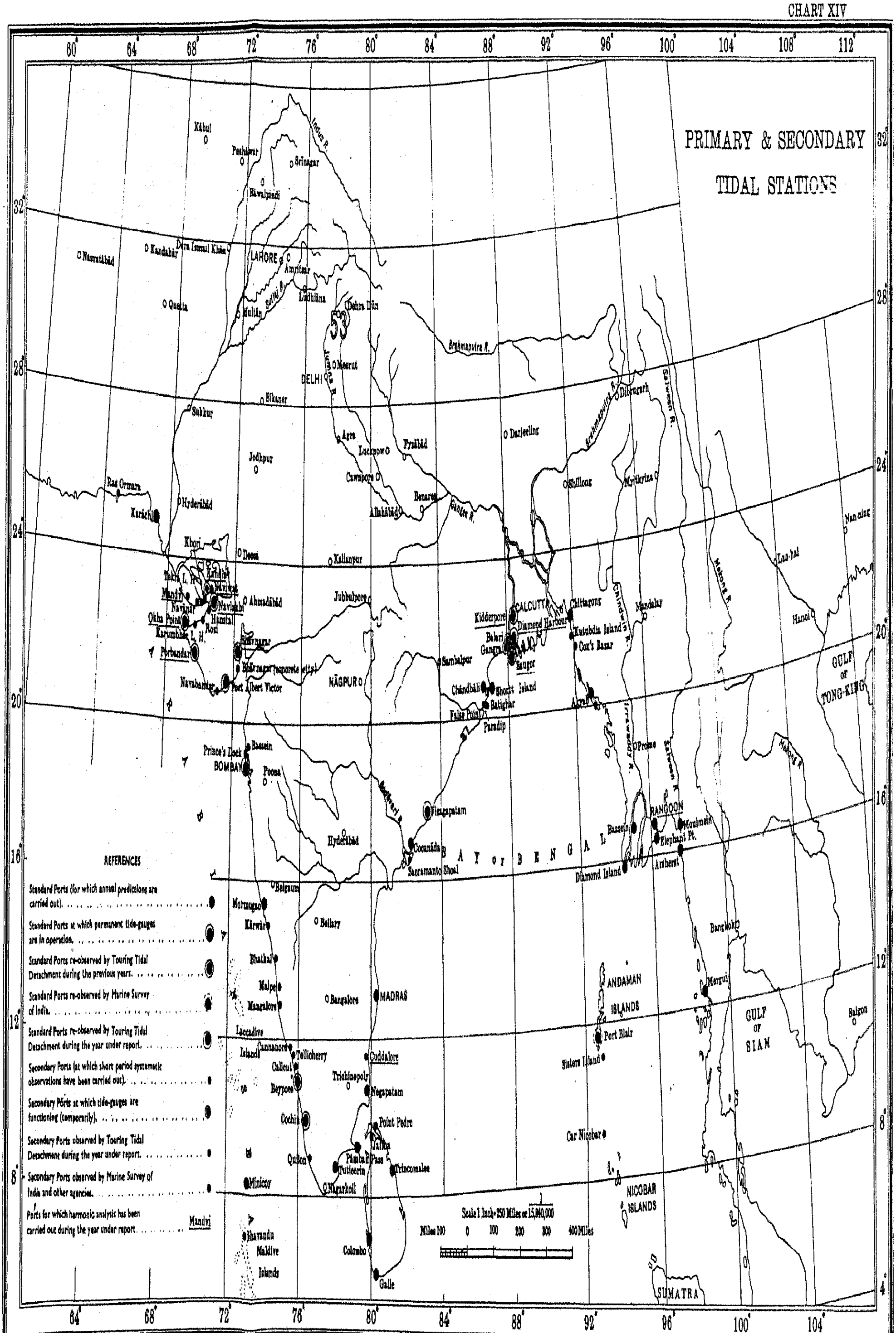
Port	Dates of breaks	Remarks
Bombay (Apollo Bandar)	2nd–3rd June 1950	Due to inspection of the gauge.
	29th June–1st July 1950	Due to sticking of pencil.
Vizagapatam ..	20th September–12th October 1950	Due to overhauling and repairs of gauge (Daylight observations of H.W. and L.W. on tide-pole carried out for this break period).
Kandla ..	11th–12th November 1950	Due to wire going off the pulley.

The records have on the whole been satisfactory, except at Kandla, where owing to the limitations of the present pencil screw (of one-inch pitch) in the instrument, the registrations of certain extreme tides have been missed. Action is in hand to obtain a new pencil screw (of half-inch pitch) to overcome this difficulty.

The Bombay observatory was inspected by the Surveyor of the Port Trust in June 1950 ; and that at Calcutta (Garden Reach) by the Officer-in-charge, Encroachment and Port Survey Party in

* Reports of observations at Karāchi and Chittagong in Pākistān have not been received since March 1948, but it is presumed that observations have been in progress.

CHART XIV



Reg. No. 72 D/N.C.D.'52 (G. & T. C.Scale 1"-250 Miles)-375

Printed at the Survey of India Offices,(P. Z. O.).

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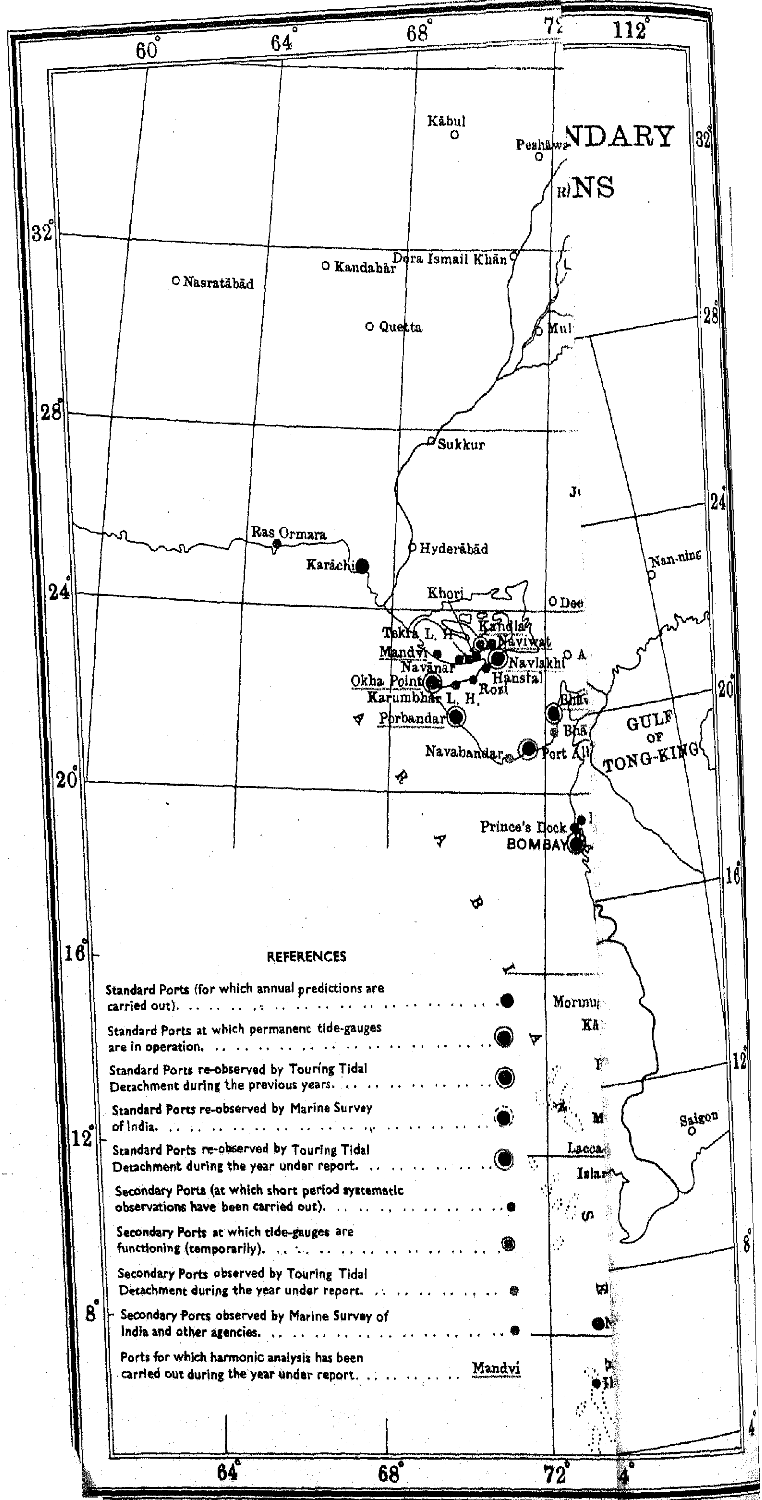


Reg. No. 72 D/NC.D.'52 (G. & T. C. Scale 1"=250 Miles)-375. Offices,(P. Z. O.)

December 1950. No inspection reports were received from Aden, except that intimation was received that the float-well was thoroughly cleaned during August 1950.

(*b*) *By touring tidal detachment of the Survey of India.*—A series of 31 days' systematic observations on tide-pole was carried out by a tidal detachment, under Mr. A. K. Banerji (Surveyor) at each of the ports, Port Albert Victor, Navabandar and Bhāvnagar concrete jetty in the Gulf of Cambay (see Chart XIV). The object of the observations was to check the existing tidal constants in the case of Port Albert Victor (Standard Port), and to obtain necessary information, for navigational purposes, in the other two cases (Secondary Ports). The observations consisted, as usual, of readings at intervals of every half-hour during both day and night, and also at the times of high and low waters.

It had originally been proposed to carry out similar 31 days' observations at Gopinath Point (Secondary Port at the mouth of the Gulf) as well, but the site was found unsuitable for the installation of the ordinary tide-pole and the proposal had to be dropped.

The detachment consisting of Mr. Banerji (Officer-in-Charge), two computers, two recorders and 6 *khalāsīs* left Dehra Dūn for the field on 2nd November 1950, and returned to headquarters, after completion of the programme, on 19th March 1951. The health of the detachment remained satisfactory throughout the season.

(*c*) *By the Marine Survey of India.*—In the course of their hydrographic survey operations in the Andaman—Nicobar waters, a party of the Marine Survey Department carried out short period observations on tide-poles at the following places on the Andaman and Nicobar coasts :—

(i)	Duncan Passage (Sisters Islands) ..	Period 15 days	(23–2–51 to 9–3–51)
(ii)	Aberdeen Jetty (Opposite Ross Island) ..	,, 16 ,,	(23–2–51 to 10–3–51)
(iii)	Malacca Jetty (Car Nicobar Island). ..	,, 32 ,,	(15–3–51 to 15–4–51)

The observations consisted of continuous readings at intervals of every half an hour covering both day and night. The data have been forwarded to this Department for necessary reduction and analysis.

38. **Analysis of observations.**—Work on harmonic analysis and reduction of tidal observations was never so heavy during any of the previous years as during the year under report. Mention had been made in the last year's report about Mr. A. N. Ramanathan (Deputy Superintending Surveyor) having been deputed abroad for a course of advanced studies at the Liverpool Observatory and Tidal Institute, with a view to adopting the latest methods in the analysis and prediction processes in India and improving the quality

of the Indian tide-tables. Soon after his return to India in May 1950, the work of introducing these new methods and processes in the Department was actively taken in hand, involving considerable labour. Results of the analysis had been, in certain cases (e.g., Hooghly River ports, Kandla and neighbouring ports), required specially urgently in connection with the ports' development projects.

The following are details of the various analyses that were carried out :—

(*a*) *24-hour analysis.*—Special short-period observations, covering about 24 hours during both springs and neaps, had been taken by the Calcutta Port Commissioners at the Saugor Sandheads (about 40 miles southward of the Hooghly delta) and forwarded to this office for analysis. The results were to be used for certain special predictions for Lower Saugor, required in connection with the construction of a tidal model of the Hooghly at the Poona Central Waterways, Irrigation and Navigation Research Station. In the analysis, use was made of the simultaneous observations that were in progress at the Standard Port of Saugor at the delta. The resulting constants have been tabulated in Table 1.

(*b*) *29-day analysis.*—The field observations of 1949–50 that had been carried out at Navlakhi and Navi Wat in the Gulf of Kutch were analysed by the latest method, yielding 28 components, as against 9 components obtainable by the Admiralty method followed hitherto. The results of the analyses are given in Table 2(*a*).

In the case of Navlakhi (Standard Port), the constants which have hitherto been in use for standard predictions in the tide-tables, are also shown in the table for comparison. This station has a high tidal range of 23 feet and the change that appears to have taken place in certain constants can be regarded as insignificant.

The field observations of season 1948–49 which had been carried out at Mandvi, Port Okha, Porbandar and Bhāvnagar and which had been analysed by the Admiralty method last year, were re-analysed this year by the more elaborate method mentioned above, for a comparative study. The revised values of the harmonic constants, which can now be accepted in preference to those published last year, are given in Table 2(*b*). Similar re-analysis was done also in the case of the observations for Kandla, where predictions that were required in connection with the port's development project, were to be based on a 29-day analysis only. The revised constants for this port are also included in the above table.

Analysis of 29 days' observations was also carried out in respect of the secondary port Cuddalore, some old observational data for which became available recently. The values of the constants are given in Table 2(*c*). These values can now be accepted in place of the "inferred" constants published in the Admiralty Tide-Tables, Part II (1938 edition).

(*c*) *One-year analysis.*—The regular analysis of one full year's data, by the Liverpool Institute's method of intensive analysis*, was carried out in the case of Port Saugor (Hooghly River) from the observations of 1948. This was the initial or primary analysis, on which the harmonic shallow water analyses (see sub-para below) for this, as well as the other ports situated higher up the river, were to be based. The results of this primary analysis are given in Table 3.

Similar intensive analysis is now in hand for the port of Kandla as well. In view of this port being in the process of development as a major port in India, it is proposed to include annual standard predictions for it in the "Tide-Tables of the Indian Ocean" commencing with the 1953 publication. The analysis is now in an advanced stage of completion.

(*d*) *Harmonic shallow water analysis.*—Mention has already been made in the last two Technical Reports about the application of harmonic shallow water analysis for riverain predictions. The data for the analysis comprise the (Actual—Predicted) residuals for a minimum period of one year, for each port.

The preliminary analysis of Rangoon (1941-observations) which had been taken up last year, as an experiment, was completed by Mr. Ramanathan at Liverpool in the course of his studies there. The primary constants that were used for the basic predictions and the harmonic shallow water constants that were obtained from the analysis have been separately tabulated in Tables 4(*a*) and 4(*b*).

The shallow water analysis for Saugor, Diamond Harbour and Kidderpore were also taken up and completed during the year, on the lines indicated in the last year's Technical Report. Part of the analysis, in the case of Saugor and Kidderpore, was carried out at Liverpool. The observational data used in each case for the analysis were those of the year 1948. Time did not permit more than the first approximation analysis to be completed in the case of Saugor and Diamond Harbour, while in the case of Kidderpore

* This method is described in detail in the Phil. Trans. of Royal Society of London, Series A, Vol. 227, pp. 223–279.

it was possible to carry out a second approximation analysis as well and use the results for the 1952-standard predictions. Results of the above analyses (all based on Saugor primary predictions obtained from constants of Table 3) are shown in Tables 6 to 8. The time and height corrections that were applied to the Saugor primary predictions to get the primary predictions in the case of Diamond Harbour and Kidderpore, are shown in Table 5.

The second approximation analysis in the case of Saugor and Diamond Harbour is now in progress and is expected to be completed in time for the 1953-standard predictions. Results of the analysis will be published in the next Technical Report.

39. **Tidal Predictions.**—During the period under report, the preparation of the annual tide-tables for the Indian Ocean ports for 1951 was completed, and that for the years 1952 and 1953 was continued. Preliminary computations for the machine settings for 1954 were also taken in hand.

The "Tide-Tables of the Indian Ocean, 1951" and the separate pamphlets for Bombay port and the Rangoon River for 1951 were published in the month of April 1950. The tidal pamphlet for the Hooghly River (3 ports) was published in the month of August.

The Tide-Tables relating to the year 1952 are now at the press, in various stages of printing. Proofs of predictions for 53 ports (out of a total of 67 required for the Tide-Tables) have already been examined and passed for printing.

Advanced tidal predictions for 16 ports for the year 1952 were despatched, in accordance with the standing International arrangements for exchange of official predictions, to the Hydrographic Department of Britain, the United States and Portugal in the month of August. Predictions for one more port, viz., Saugor, for 1952 (prepared according to the Liverpool Institute's method of harmonic shallow water corrections) were despatched to the former two institutions in November 1950. Advance predictions for 3 ports for 1952 were also supplied, as usual, to the Royal Indian Navy during the above period.

Special tidal predictions for the Saugor Sandheads (Lower Saugor) were prepared for certain specified lunations of the year 1939 and supplied to the Central Waterways, Irrigation and Navigation Research Station, Poona in connection with the construction of a tidal model of the Hooghly. The request for these predictions had been received from the Calcutta Port Commissioners.

Also, tidal predictions for Kandla port for the year 1951 were prepared and supplied, in manuscript form, to the port authorities at their request. The predictions were asked for in connection with the port's development project.

The total realization from the sale of Tide-Tables, exclusive of Agents' commission, during the year under report amounted to Rs. 4,785/14/-. The sum received up-to-date on account of paid-for work done during the year, and on account of Royalties, amounted to Rs. 3,400/-.

40. **Harmonic Shallow Water Predictions.**—In the method of Harmonic Shallow Water Corrections (H.S.W.C.), adopted in place of the old riverain method for the predictions of the Hooghly River ports (Saugor, Diamond Harbour and Calcutta) commencing from 1952, each shallow water constituent is set up on the tide-predicting machine by using one of the constituents already represented, or by using any of the diurnal or semi-diurnal constituents contributing to the compound constituent. For example, the shallow water constituent C (27) is set up on K_2 or MK_4 or $2MK_6$, etc. The readings of the machine are taken at intervals of 12 lunar hours, and these readings (corrections) are attributed to the corresponding high water or low water of the primary predictions. The machine is run separately four times to give corrections to the high water heights, high water times, low water heights and low water times.

The present Indian tide-predicting machine has only a few components that are directly adoptable for shallow water settings. Consequently certain improvisations have had to be resorted to for obtaining the machine predictions. The "Kelvin machine method" of Harmonic Shallow Water Corrections predictions has been adopted, with the C and C′ groups of Harmonic Shallow Water constituents set and run separately for each of the series of the high and low water times and heights, thus necessitating 8 separate runnings. Further, due to lack of proper setting components, corrections to the phase angles are required to be made at intervals of every "machine day" (27½ lunar days) instead of at four times that interval, thus involving considerable additional labour. The machine, as it stands, does not also have the necessary parts and fittings for this kind of predictions, and certain attachments like scales, pen-indicators, etc., have had to be improvised for immediate use, pending more permanent arrangements.

41. **Corrections to Predictions.**—Empirical corrections, based on the observations of recent years, were, as usual, applied to the predictions for Karāchi, Navlakhi, Bhāvnagar, Bombay (Apollo Bandar), Vizagapatam, Chandbali and Rangoon, for the year 1953. Except for Bhāvnagar and Rangoon, the corrections were the same as those applied to the 1952 predictions (see Technical Report 1949–50, Part III). The revised corrections in the case of Bhāvnagar and Rangoon are given in Tables 9 to 11.

In the case of Saugor, Diamond Harbour and Calcutta, as the method of Harmonic Shallow Water Corrections was adopted for the predictions commencing from 1952, no empirical corrections were required.

42. **Accuracy of Predictions.**—Tables 12–19 give details of the discrepancies between the predicted and observed tides, during

1950, at the places where "actuals" were observed, and Table 20 gives the greatest errors in the predicted heights of low waters at these places during the same year. The general quality of the predictions can be seen to have practically remained the same as before.

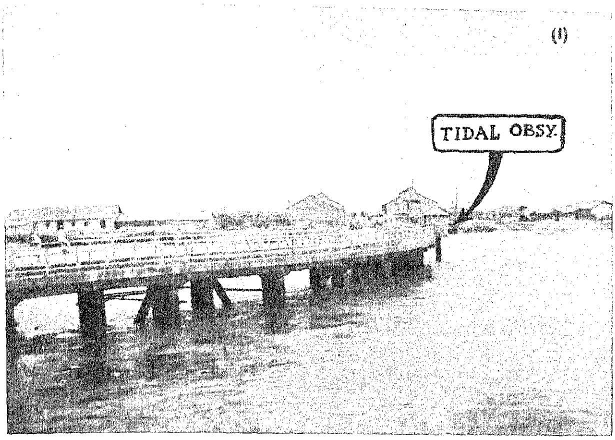
The new method of Harmonic Shallow Water Corrections that is now being introduced in the department for riverain predictions, is going to be a distinct improvement over the method that was being followed hitherto. Table 21 shows the comparative accuracy in the predictions (1948) by the new and old methods in the cases of a few ports where the new method has been tried out as an experiment. The results are very encouraging.

43. **Miscellaneous.**—A new tide-predicting machine, equipped with 42 components, is now on order from the United Kingdom, to replace the existing tide machine which is not only practically worn-out (having served for over 73 years) but is also not adequately equipped to meet the needs in the case of complicated ports like Calcutta, Kandla, Cochin, etc., where the effects of shallow water, meteorological conditions and so on, are very considerable. The machine is being constructed by Messrs. Légé & Co., under the supervision of Dr. Doodson of the Liverpool Tidal Institute, and is expected to be ready for shipment to India by the end of 1951.

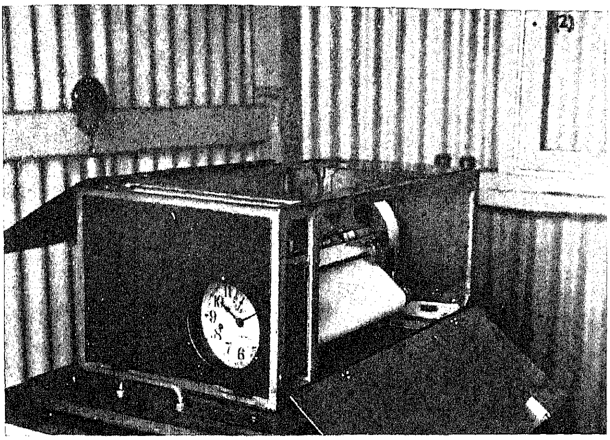
Six new tide-gauges, of the Légé-vertical type, are also on order from the United Kingdom. These have been asked for in order to meet the pressing demands for modern observational data at ports where development projects are under way.

44. **Tidal Observatories.**—A new tidal observatory has been established at Kandla and it is proposed to open one at Port Blair in the near future. These observatories are described below :—

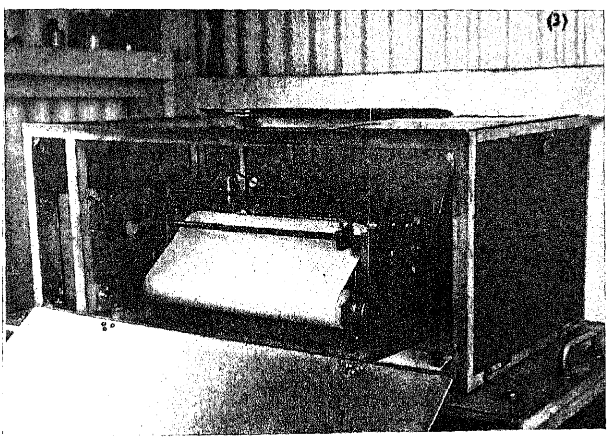
(*a*) *The Kandla Tidal Observatory.*—The Tidal Observatory at Kandla is situated at a deep-water site, on the north side of the reinforced concrete jetty and at about a hundred feet from the west bank of the Kandla Creek, in the position shown on the photograph No. 1 in Plate XIV. The tide-house is a wooden cabin, of size about 8 feet × 8 feet × 10 feet, and rests on two iron-rail upstarts from the piles of the jetty, suitably cross-joined for stability. The float cylinder is made up of four uniform reinforced concrete pipes, one resting plumb over the other, the pipes being kept in position by means of an outside cage formed by four long angle-iron flanges cross-joined at intervals. The cage is over 40 feet long, with one end firmly driven down into the ground, and the other end secured firmly to the floor of the observatory. The cylinder rests on an iron platform within the cage, situated about 4 feet below the lowest possible low water level. The top of the cylinder just reaches the



(1)
Tidal
observatory
at
KĀNDLA



(2) & (3)
Views
of the
Tide-gauge
functioning
inside the
observatory



floor of the observatory and is over 4 feet above the highest possible high water. The communication to the cylinder is through a number of holes (each about an inch in diameter) provided a few inches above its bottom.

Photograph Nos. 2 and 3 in Plate XV show two views of the U.S.A. tide-gauge functioning inside the observatory. Unlike the Newman's pattern, this U.S.A. tide-gauge works on two clocks, one of the clocks being used for recording the time and the other for driving the drum. Further, instead of a graduated paper being wound round the drum, this gauge provides for two small rollers, a supply roller and a receiving roller, by which about 66 feet of blank paper (sufficient for one month's continuous record), wound round the supply roller, is arranged to pass over the main drum and eventually wind round the receiving roller by means of suitable counterpoise. A recording pencil actuated by the rising and falling float inside the cylinder, registers the tidal movements on the moving paper, while another pencil, fixed to the frame of the instrument, records the fixed datum. A full description of the tide-gauge is contained in the U.S. Coast and Geodetic Survey Special Publication No. 196.

The zero of the gauge has been set to coincide with the level of the chart datum, which is 26 ·99 feet below the Marine Survey bench-mark, marked BM $\overset{\square}{\uparrow}$ +26 ·99 and situated on the south parapet of the jetty. The height of the bed-plate above the zero of the gauge is 30 ·881 feet. A reference tide-staff has also been installed (fixed to one of the jetty-piles) close to the observatory, with its zero set to agree with the chart datum, i.e., with the zero of the tide-gauge.

The mean establishment of the port has been calculated to be 02h. 26m. The mean range of largest ordinary spring tides is 22 ·1 feet, while the mean rise during such springs is 22·6 feet. The local mean sea-level has been found from an year's observations (1950) to be 12 ·45 feet above the chart datum or 14 ·54 feet below the bench-mark of reference (BM $\overset{\square}{\uparrow}$ +26 ·99).

(*b*) *Port Blair Tidal Observatory.*—A Tidal Observatory equipped with a self-registering tide-gauge was established in Ross Island in 1880. Mean sea-level was determined from 1880–86 observations. It was 3 ·532 feet above the Indian spring low water mark and 4 ·708 feet above the zero of the gauge. The reference bench-mark was 7 ·766 feet above mean

sea-level. This bench-mark had worn out by 1884 and another mark known as bench-mark 'C' was constructed in 1898, its height being 13·267 feet above the zero of the tide-gauge and 8·507 feet above mean sea-level (as determined from 41 years' observations).

The tidal observations were discontinued in 1925 when the tide-gauge was dismantled and brought to Dehra Dūn. To improve the tidal predictions and to obtain sea-level data for various geodetic and geophysical investigations, it is proposed to re-establish a permanent tidal observatory at Port Blair. The observations would be of considerable interest as these islands are suspected to be rising.

Ross Island has an area of only ¼ square mile and used to be the administrative headquarters of the Penal Settlement of Port Blair. The residential portion was completely destroyed by allied bombing during the Japanese occupation in the last war and it has now been abandoned.

A site for the tidal observatory has now been selected on the main land on the south side of the Aberdeen jetty. Great care had to be exercised in its selection as cyclones are a common feature in the Bay of Bengal, and the Andamans come within their ambit.

The old bench-mark of reference on Ross Island has been found intact and has been connected to the levelling on the main land. The construction of the observatory is in hand and it is hoped to make a start with the observations during the coming cold weather.

Exact details of the tide-house, gauge zero, and its relation with the datum and bench-mark of reference for the new observatory will be given in the next Technical Report.

TABLE 1.—*Harmonic Tidal Constants derived from 24-hour analysis*
(Liverpool Institute's method of analysis)

Place**:** SAUGOR SANDHEADS (LOWER SAUGOR)

Latitude	Longitude	Standard time	Period of observations	
21° 11′ N.	88° 16′ E.	I.S.T.	24 hours	(3rd/4th March 1949)

Standard port for simultaneous reduction——SAUGOR

	H. ft.	g°		H. ft.	g°		H. ft.	g°		H. ft.	g°
Z_0*	10·68		$2Q_1$			OQ_2			MO_3	0·007	330
Sa†	0·906	147	σ_1			MNS_2			M_3		
Ssa†	0·207	124	Q_1	0·010	069	$2N_2$	0·114	246	SO_3		
Mm			ρ_1			μ_2	0·081	350	MK_3	0·011	079
MSf			O_1	0·139	342	N_2	0·625	242	SK_3		
Mf			MP_1			ν_2	0·153	236			
			M_1			OP_2			MN_4	0·016	092
			χ_1			M_2	3·179	255	M_4	0·032	113
			π_1			MKS_2			SN_4		
			P_1	0·118	359	λ_2			MS_4	0·033	150
			S_1	0·052	142	L_2	0·149	269	MK_4		
			K_1	0·397	001	T_2	0·125	336	S_4		
			ψ_1			S_2	1·500	295	SK_4		
			ϕ_1			R_2					
			θ_1			K_2	0·432	293	$2MN_6$		
			J_1	0·019	012	MSN_2			M_6	0·023	009
			SO_1			KJ_2			MSN_6		
			OO_1			$2SM_2$	0·037	198	$2MS_6$		
									$2MK_6$		
									$2SM_6$		
									MSK_6		

* M.S.L. above chart datum.
† Saugor values accepted.

TABLE 2(*a*).—*Harmonic Tidal Constants derived from 29 days' analysis* (Liverpool Institute's method of analysis)

		1				2	
Place and Position with Description of Tide-pole		NAVLAKHI* Lat. 22° 58′ N. Long. 70° 27′ E.				NAVI WAT Lat. 23° 05′ N. Long. 70° 20′ E.	
		Tide-pole at end of pier (Warsamedi creek)		Tide-pole at passenger jetty (Sui creek)		Tide-pole fixed on the junction of Navi Wat and Morwali creeks	
Period of observations and Central day		one year 1–6–32		29 days 29–1–50		29 days 21–3–50	
Time Meridian		*Indian Standard Time (05h 30m fast on G.M.T.)*					
Level of zero of Tide-pole	Below chart datum	0·50 ft.		6·48 ft.		..	
	Below B.M. of reference	27·00 ft.		31·06 ft.		25·08 ft.	
Harmonic Constants		Old (1932)		New (1950)			
		H. ft.	g°	H. ft.	g°	H. ft.	g°
M_m	.. ..	0·10	001	0·02	152	0·40	039
MS_f	.. ..	0·18	043	0·25	052	0·39	049
Q_1	.. ..	0·17	078	0·18	071	0·16	086
O_1	.. ..	0·79	084	0·94	079	0·71	075
P_1	.. ..	0·47	099	0·60	090	0·58	099
K_1	.. ..	1·68	098	1·80	091	1·75	101
J_1	.. ..	0·14	157	0·11	199	0·09	181
$2N_2$	.. ..	0·33	312	0·14	037	0·23	071
μ_2	.. ..	0·68	190	0·75	154	1·03	195
N_2	.. ..	1·62	060	1·33	052	1·67	067
ν_2	.. ..	0·43	015	0·26	055	0·32	069
M_2	.. ..	8·12	078	8·20	073	7·39	083
L_2	.. ..	0·82	070	0·40	088	0·82	055
T_2	.. ..	0·33	194	0·13	121	0·12	129
S_2	.. ..	2·22	129	2·27	123	2·00	131
K_2	.. ..	0·60	126	0·62	127	0·55	135
$2SM_2$	.. ..	0·17	342	0·22	302	0·18	344
MO_3	.. ..	0·15	266	0·13	252	0·09	234
M_3	.. ..	0·11	242	0·13	198	0·06	245
MK_3	.. ..	0·12	016	0·23	347	0·13	084
MN_4	.. ..	0·33	003	0·28	001	0·42	037
M_4	.. ..	0·68	024	0·73	024	0·75	057
MS_4	.. ..	0·41	072	0·37	069	0·47	106
MK_4	.. ..	..	..	0·10	073	0·13	110
$2MN_6$	.. ..	..	..	0·12	293	0·21	335
M_6	.. ..	0·25	295	0·24	291	0·21	350
$2MS_6$	.. ..	..	..	0·24	330	0·23	024
$2SM_6$	.. ..	..	..	0·07	029	0·06	072
Height of M.S.L.	above chart datum = Z_0	13·61 ft.		13·60† ft.		..	
	above T.P. zero = S_0	..		..		14·83† ft.	
Description of B.M. of reference.		Marine Survey B.M.† cut on the pier under top step (Reported missing in 1949–50).		G.T.S. □ (Type B) B.M. embedded 1 foot below ground level, near SW. corner of the passenger shed opposite Navlakhi Railway Station. It is 2 feet W. of W. wall of the shed, 69 feet from the gate of the jetty and 37 feet E. of E. wall of another building.		G.T.S. B.OM. (Type B) A.D. 1950 situated about 40 yds. E. of the tide-pole site and is surrounded by a mud wall 2·5 feet high.	

* Standard Port.
† Corrected for seasonal variations.

TABLE 2(*b*).—*Harmonic Tidal Constants derived from 29 days' analysis* (Liverpool Institute's method of analysis)

		1		2		3		4		5	
Place and Position with Description of Tide-pole		MANDVI Lat.: 22° 50′ N. Long.: 69° 21′ E.		PORT OKHA* Lat.: 22° 28′ N. Long.: 69° 05′ E.		POR-BANDAR* Lat.: 21° 38′ N. Long.: 69° 37′ E.		BHĀV-NAGAR* Lat.: 21° 48′ N. Long.: 72° 09′ E.		KANDLA Lat.: 23° 02′ N. Long.: 70° 14′ E.	
		At the south end of the break water pier		About 100 yds. SE. of the old tide-gauge site		At Asmavathi Ghat near Shiva Temple and at the bend of the creek		About 10 ft. north of the old tide-gauge site		At Kandla Timber jetty	
Central day of analysis		19–12–48		12–11–48		30–1–49		4–3–49		4–9–49	
Time Meridian		*Indian Standard Time (05h 30m fast on G.M.T.)*									
Level of zero of Tide-pole	Below chart datum	1·39† ft.		3·99 ft.		2·95 ft.		0·07 ft.		−0·01 ft.	
	Below B.M. of reference	23·87 ft.		21·14 ft.		24·75 ft.		40·50 ft.		26·98 ft.	
Harmonic Constants		H. ft.	g°	H. ft.	g°	H. ft.	g°	H. ft.	g°	H. ft.	g°
Mm		0·08	020	0·52	314	0·21	089	0·48	019	0·17	145
MSf		0·11	272	0·21	169	0·18	091	0·39	062	0·26	011
Q_1		0·17	063	0·13	051	0·14	054	0·25	069	0·18	072
O_1		0·74	079	0·65	063	0·58	054	1·12	075	0·78	072
P_1		0·48	075	0·46	065	0·45	056	0·83	090	0·54	086
K_1		1·46	075	1·40	065	1·35	056	2·50	092	1·62	087
J_1		0·07	189	0·07	047	0·14	098	0·12	146	0·10	195
$2N_2$		0·09	347	0·11	295	0·07	294	0·38	099	0·22	053
μ_2		0·22	197	0·23	226	0·08	319	0·06	256	1·14	178
N_2		0·79	010	0·92	341	0·50	292	2·47	117	1·50	050
ν_2		0·15	014	0·18	297	0·10	295	0·48	120	0·29	052
M_2		4·09	042	3·65	011	2·20	311	10·30	143	7·60	065
L_2		0·28	112	0·12	112	0·10	268	1·03	169	0·96	023
T_2		0·07	079	0·06	039	0·05	348	0·19	188	0·15	108
S_2		1·17	080	1·10	040	0·78	350	3·16	190	2·47	110
K_2		0·32	083	0·30	042	0·21	353	0·86	194	0·67	113
$2SM_2$		0·09	140	0·04	349	0·04	330	0·18	046	0·05	284
MO_3		0·05	301	0·04	306	0·01	303	0·13	022	0·08	280
M_3		0·04	274	0·01	035	0·02	322	0·06	351	0·12	199
MK_3		0·05	334	0·01	270	0·00	327	0·48	165	0·30	001
MN_4		0·05	211	0·06	126	0·02	016	0·47	165	0·22	345
M_4		0·13	232	0·11	163	0·03	146	1·00	190	0·54	006
MS_4		0·06	304	0·01	175	0·02	350	0·70	240	0·34	040
MK_4		0·02	307	0·00	178	0·01	354	0·19	244	0·09	043
$2MN_6$		0·03	001	0·01	010	0·02	356	0·22	172	0·13	248
M_6		0·06	093	0·03	250	0·01	023	0·36	212	0·21	305
$2MS_6$		0·06	184	0·01	320	0·00	274	0·32	239	0·27	341
$2SM_6$		0·02	223	0·00	349	0·00	313	0·10	286	0·08	016
Height of local M.S.L. above chart datum = Z_0		8·5‡ ft.		6·84† ft.		5·95† ft.		20·44† ft.		12·32† ft.	
Description of B.M. of reference		See Technical Report 1950, Part III									

* Standard ports.
† Corrected for seasonal variations.
‡ Provisional value.

TABLE 2(*c*)—*Harmonic Tidal Constants derived from 29 days' analysis* (Liverpool Institute's method of analysis)

Place: CUDDALORE

Latitude	Longitude	Standard time	Observational data	
			Length	Central day
11° 43′ N.	79° 47′ E.	I.S.T.	29 days	8th March 1929

Position of tide-pole: Erected just inside bar.
Description of B.M. of reference :—
A square stone-marked G.T.S. which is embedded on a flat concrete platform and which is 14 feet and 100° from the centre of Cuddalore Lighthouse. The stone marks the position in which Cuddalore Beacon existed.

Level of zero of Tide-pole below	
Chart datum (or zero of prediction)	4·00 ft.
B.M. of reference	47·14 ft.

	H. ft.	g°		H. ft.	g°		H. ft.	g°		H. ft.	g°
Z_0*	2·08		$2Q_1$			OQ_2			MO_3	0·01	174
Sa			δ_1			MNS_2			M_3	0·01	043
Ssa			Q_1	0·01	206	$2N_2$	0·02	242	SO_3		
Mm	0·17	013	ρ_1			μ_2	0·04	279	MK_3	0·01	141
MSf	0·05	273	O_1	0·06	308	N_2	0·17	243	SK_3		
Mf			MP_1			ν_2	0·03	243			
			M_1			OP_2			MN_4	0·01	357
			χ_1			M_2	0·85	241	M_4	0·01	003
			π_1			MKS_2			SN_4		
			P_1	0·11	341	λ_2			MS_4	0·00	220
			S_1			L_2	0·04	235	MK_4	0·00	224
			K_1	0·32	344	T_2	0·02	283	S_4		
			ψ_1			S_2	0·35	284	SK_4		
			ψ_1			R_2					
			θ_1			K_2	0·09	288	$2MN_6$	0·02	005
			J_1	0·01	180	MSN_2			M_6	0·02	333
			SO_1			KJ_2			MSN_6		
			OO_1			$2SM_2$	0·00	214	$2MS_6$	0·02	007
									$2MK_6$		
									$2SM_6$	0·01	050
									MSK_6		

*** M.S.L. above chart datum, corrected for seasonal variations.**

TABLE 3.—*Harmonic Tidal Constants derived from 1-year analysis* (Liverpool Institute's method)

Place : SAUGOR (HOOGHLY)

Latitude	Longitude	Standard time	Observational data	
			Length	Central day
21° 39′ N.	88° 03′ E.	I.S.T.	1 year	1st August 1948

Position of Tide-gauge : *Saugor Semaphore*
Description of B.M. of reference :—

On top of rail projecting about 9 inches above ground level, embedded in a block of masonry and situated 77 feet N. of the Saugor Semaphore and about 3/4 mile SW. of the Saugor Lighthouse.

Level of zero of Tide-gauge below	
Chart Datum	0·000 ft.
B.M. of reference	19·550 ft.

	H. ft.	g°		H. ft.	g°		H. ft.	g°		H. ft.	g°
Z_0*	10·555		$2Q_1$	0·011	036	OQ_2	0·025	106	MO_3†	0·022	084
Sa	0·906†	147	σ_1	0·013	040	MNS_2	0·052	341	M_3	0·063	103
Ssa	0·207†	124	Q_1†	0·012	054	$2N_2$†	0·165	266	SO_3	0·009	002
Mm	0·034	323	ρ_1	0·008	325	μ_2†	0·117	010	MK_3†	0·038	192
MSf	0·057	138	O_1†	0·172	327	N_2†	0·905	262	SK_3	0·080	218
Mf	0·024	060	MP_1	0·017	181	ν_2†	0·222	256			
			M_1	0·020	337	OP_2	0·042	270	MN_4†	0·077	112
			χ_1	0·018	235	M_2†	4·601	275	M_4†	0·156	133
			π_1	0·013	336	MKS_2	0·020	253	SN_4	0·029	142
			P_1†	0·147	343	λ_2	0·080	288	MS_4†	0·158	170
			S_1†	0·065	126	L_2†	0·215	289	MK_4	0·050	169
			K_1†	0·493	345	T_2†	0·181	355	S_4	0·039	193
			ψ_1	0·024	114	S_2†	2·170	315	SK_4	0·021	228
			ϕ_1	0·020	025	R_2	0·150	290			
			θ_1	0·014	318	K_2†	0·625	313	$2MN_6$	0·012	161
			J_1†	0·024	356	MSN_2	0·048	158	M_6†	0·037	163
			SO_1	0·017	167	KJ_2	0·025	213	MSN_6	0·016	199
			OO_1	0·028	346	$2SM_2$†	0·053	217	$2MS_6$	0·069	197
									$2MK_6$	0·023	188
									$2SM_6$	0·015	228
									MSK_6	0·010	236

* M.S.L. above chart datum.
† Components of the Indian Tide-machine.

TABLE 4(*a*)—*Harmonic Tidal Constants derived from 10 years' annual analysis* (B.A. method of analysis)

Place: RANGOON (BROOKING STREET)

Latitude	Longitude	Standard time	Observational data	
			Length	Years
16° 46′ N.	96° 10′ E.	B.S.T.	10 years	1911 to 1920

Description of B.M. of reference.:—

Scott's Bench-Mark, a concrete block one foot square, surrounded by a dwarf brick wall 4½ feet square, 2 feet in height and covered by a cast iron trap door. It is situated within a walled enclosure, at 53 feet, 211° from the Port Commissioner's flagstaff at the bottom of Lewis Street.

Level of zero of Tide-gauge below		
Chart Datum	..	0·00 ft.
B.M. of reference	..	25·08 ft.

	H. ft.	g°		H. ft.	g°		H. ft.	g°		H. ft.	g°
Z_0*	10·25		$2Q_1$			OQ_2			MO_3	0·120	040
Sa	1·246	150	δ_1			MNS_2			M_3		
Ssa	0·136	326	Q_1	0·030	026	$2N_2$	0·274	349	SO_3		
Mm			ρ_1			μ_2	0·546	277	MK_3	0·141	075
MSf			O_1	0·298	017	N_2	1·032	109	SK_3		
Mf			MP_1			ν_2	0·329	105			
			M_1			OP_2			MN_4	0·196	147
			χ_1			M_2	5·894	126	M_4	0·516	158
			π_1			MKS_2			SN_4		
			P_1	0·175	057	λ_2			MS_4	0·474	209
			S_1	0·134	135	L_2	0·448	147	MK_4		
			K_1	0·685	036	T_2	0·216	160	S_4		
			ψ_1			S_2	2·164	171	SK_4		
			ϕ_1			R_2					
			θ_1			K_2	0·597	169	$2MN_6$		
			J_1	0·042	077	MSN_2			M_6	0·248	076
			SO_1			KJ_2			MSN_6		
			OO_1			$2SM_2$	0·164	058	$2MS_6$		
									$2MK_6$		
									$2SM_6$		
									MSK_6		

* M.S.L. above chart datum.

TABLE 4(*b*).—*Harmonic Shallow Water Correction Constants* (1st approximation)

Place: RANGOON *Based on*: Rangoon basic machine* predictions
Central day of analysis: 1st July 1941 *Derived from*: (A—P)s of 1941

Constituent	H.W. heights		H.W. times		L.W. heights		L.W. times	
	R	χ	R	χ	R	χ	R	χ
	ft.	°	*min.*	°	*ft.*	°	*min.*	°
C(00)	+0·585	..	−6·49	..	−0·444	..	+27·89	..
(01)	0·146	066	8·28	318	0·355	133	3·40	258
(02)	0·269	184	1·83	060	0·132	008	4·40	338
(11)	0·337	230	8·07	155	0·355	014	5·22	114
(13)	0·251	035	3·30	086	0·204	067	10·16	059
(25)	0·645	059	4·02	020	0·237	024	18·24	016
(27)	0·293	046	4·87	219	0·285	279	1·71	045
(36)	0·138	143	3·94	021	0·019	155	3·21	347
(38)	0·161	209	3·34	273	0·285	058	2·18	270
(50)	0·135	019	4·87	237	0·085	301	3·43	218
(52)	0·046	317	1·45	320	0·094	056	2·78	202
C′(00)	−0·019	..	+0·41	..	−0·089	..	+0·93	..
(11)	0·193	022	0·94	178	0·143	113	2·25	056
(12)	0·003	012	1·43	154	0·030	349	1·76	345
(13)	0·159	045	1·70	154	0·103	310	6·65	260
(27)	0·049	074	0·57	252	0·111	171	0·64	008
(36)	0·049	253	1·07	035	0·045	108	1·19	277
(38)	0·036	096	1·09	081	0·192	315	2·07	050
(40)	0·015	303	0·60	226	0·040	311	1·13	310

* Indian Tide-machine.

TABLE 5.—*Corrections to be applied to Saugor basic predictions to obtain primary predictions for Diamond Harbour and Kidderpore*

	Date	Diamond Harbour H.W.	Diamond Harbour L.W.	Kidderpore H.W.	Kidderpore L.W.
		ft.	*ft.*	*ft.*	*ft.*
Height corrections	Jan. 1st to 10th	0·0	− 0·9	− 1·8	− 1·0
	11th to 20th	+ 0·1	− 0·9	− 1·7	− 1·0
	21st to 31st	+ 0·2	− 0·9	− 1·6	− 1·0
	Feb. 1st to 10th	+ 0·2	− 1·0	− 1·5	− 1·0
	11th to 20th	+ 0·3	− 1·0	− 1·4	− 1·0
	21st to 28th	+ 0·3	− 1·0	− 1·3	− 1·0
	Mar. 1st to 10th	+ 0·4	− 1·0	− 1·3	− 1·1
	11th to 20th	+ 0·4	− 1·0	− 1·2	− 1·2
	21st to 31st	+ 0·5	− 1·0	− 1·1	− 1·2
	April 1st to 10th	+ 0·5	− 1·1	− 0·9	− 1·1
	11th to 20th	+ 0·5	− 1·1	− 0·7	− 1·0
	21st to 30th	+ 0·6	− 1·1	− 0·6	− 1·0
	May 1st to 10th	+ 0·6	− 1·1	− 0·6	− 0·9
	11th to 20th	+ 0·7	− 1·1	− 0·6	− 0·9
	21st to 31st	+ 0·8	− 1·1	− 0·7	− 1·0
	June 1st to 10th	+ 0·8	− 1·2	− 0·8	− 1·0
	11th to 20th	+ 0·9	− 1·2	− 0·9	− 1·1
	21st to 30th	+ 1·0	− 1·2	− 0·8	− 1·0
	July 1st to 5th	+ 1·2	− 1·2	− 0·7	− 0·9
	6th to 10th	+ 1·2	− 1·2	− 0·5	− 0·7
	11th to 15th	+ 1·3	− 1·2	− 0·3	− 0·5
	16th to 20th	+ 1·3	− 1·2	0·0	− 0·3
	21st to 25th	+ 1·4	− 1·2	+ 0·3	0·0
	26th to 31st	+ 1·4	− 1·2	+ 0·7	+ 0·3
	Aug. 1st to 5th	+ 1·5	− 1·2	+ 1·1	+ 0·6
	6th to 10th	+ 1·5	− 1·2	+ 1·5	+ 0·9
	11th to 15th	+ 1·6	− 1·2	+ 1·8	+ 1·1
	16th to 20th	+ 1·6	− 1·2	+ 2·1	+ 1·3
	21st to 25th	+ 1·5	− 1·3	+ 2·1	+ 1·5
	26th to 31st	+ 1·5	− 1·3	+ 2·2	+ 1·7
	Sept. 1st to 5th	+ 1·5	− 1·3	+ 2·2	+ 1·8
	6th to 10th	+ 1·5	− 1·3	+ 2·1	+ 1·9
	11th to 15th	+ 1·4	− 1·4	+ 2·1	+ 1·9
	16th to 20th	+ 1·4	− 1·4	+ 2·0	+ 1·9
	21st to 25th	+ 1·3	− 1·5	+ 1·8	+ 1·9
	26th to 30th	+ 1·3	− 1·5	+ 1·5	+ 1·7
	Oct. 1st to 5th	+ 1·1	− 1·5	+ 1·3	+ 1·6
	6th to 10th	+ 1·1	− 1·5	+ 1·0	+ 1·3
	11th to 15th	+ 1·0	− 1·6	+ 0·7	+ 1·1
	16th to 20th	+ 1·0	− 1·6	+ 0·4	+ 0·9
	21st to 25th	+ 0·9	− 1·5	+ 0·2	+ 0·6
	26th to 31st	+ 0·9	− 1·5	− 0·1	+ 0·3
	Nov. 1st to 5th	+ 0·7	− 1·4	− 0·4	0·0
	6th to 10th	+ 0·7	− 1·4	− 0·6	− 0·3
	11th to 15th	+ 0·6	− 1·3	− 0·8	− 0·5
	16th to 20th	+ 0·6	− 1·3	− 1·0	− 0·7
	21st to 25th	+ 0·5	− 1·2	− 1·1	− 0·8
	26th to 30th	+ 0·5	− 1·2	− 1·2	− 1·0
	Dec. 1st to 5th	+ 0·3	− 1·1	− 1·4	− 1·2
	6th to 10th	+ 0·3	− 1·1	− 1·4	− 1·2
	11th to 15th	+ 0·2	− 1·0	− 1·6	− 1·4
	16th to 20th	+ 0·2	− 1·0	− 1·6	− 1·4
	21st to 25th	0·0	− 1·0	− 1·7	− 1·6
	26th to 31st	0·0	− 1·0	− 1·7	− 1·6
Time corrections	**All times**	**Add +2 hours**	**Add +3 hours**	**Add +4 hours**	**Add +6 hours**

TABLE 6.—*Harmonic Shallow Water Correction Constants*
(1st approximation)

Place : SAUGOR *Based on* : Saugor basic machine* predictions
Central day of analysis : 7th July 1948 *Derived from* : (A–P)s of 1948

Constituent	H.W. heights		H.W. times		L.W. heights		L.W. times	
	R	χ	R	χ	R	χ	R	χ
	ft.	°	*min.*	°	*ft.*	°	*min.*	°
C (00)	+0·057	..	+5·01	..	−0·024	..	+8·03	..
(01)	0·178	135	12·79	302	0·120	280	12·76	307
(02)	0·048	273	1·75	284	0·043	357	2·68	342
(11)	0·109	213	3·93	146	0·076	323	2·50	094
(13)	0·034	182	2·68	124	0·032	314	0·68	184
(25)	0·049	121	2·45	009	0·044	215	4·46	355
(27)	0·069	345	2·03	275	0·112	009	3·84	031
(36)	0·046	239	1·79	012	0·016	276	0·93	325
(38)	0·024	286	2·55	055	0·052	062	2·84	057
(50)	0·091	069	3·49	237	0·044	352	2·17	178
(52)	0·017	160	1·24	266	0·028	342	2·85	256
C′ (00)	+0·000	..	−1·59	..	+0·008	..	+1·43	..
(11)	0·031	144	0·55	337	0·047	267	0·46	216
(12)	0·036	111	0·46	134	0·019	179	0·99	110
(13)	0·018	083	1·22	266	0·047	132	1·55	276
(27)	0·017	096	0·60	015	0·019	152	1·37	156
(36)	0·017	245	1·29	185	0·028	008	1·03	050
(38)	0·038	051	0·78	012	0·031	162	0·83	268
(40)	0·051	107	1·34	026	0·061	025	0·71	200

* Indian Tide-machine.

TABLE 7.—*Harmonic Shallow Water Correction Constants* (1st approximation)

Place: DIAMOND HARBOUR *Based on*: Saugor basic predictions

Central day of analysis: 1st July 1948 *Derived from* (A−P)s of 1948

Constituent	H.W. heights		H.W. times		L.W. heights		L.W. times	
	R	χ	R	χ	R	χ	R	χ
	ft.	°	*min.*	°	*ft.*	°	*min.*	°
C (00)	−0·022	..	−21·073	..	+0·007	..	−14·213	..
(01)	0·058	356	12·521	305	0·072	130	13·249	308
(02)	0·146	064	5·269	241	0·038	016	6·391	299
(11)	0·069	190	4·307	172	0·074	318	2·871	180
(13)	0·097	064	3·086	178	0·100	001	5·983	359
(25)	0·217	057	0·517	150	0·206	009	27·100	020
(27)	0·156	023	1·382	175	0·136	355	10·064	039
(36)	0·046	184	4·275	011	0·016	231	5·061	008
(38)	0·060	031	1·672	132	0·115	007	3·779	063
(50)	0·111	069	6·209	238	0·018	032	7·799	216
(52)	0·068	046	4·048	245	0·038	358	6·538	237
C′ (00)	−0·001	..	− 1·157	..	−0·001	..	− 1·296	..
(11)	0·025	164	0·228	118	0·036	239	1·643	019
(12)	0·047	085	1·434	016	0·015	293	0·839	192
(13)	0·090	082	3·360	293	0·054	203	3·424	232
(27)	0·018	138	0·443	327	0·036	212	2·085	174
(36)	0·029	282	2·488	186	0·026	062	1·257	088
(38)	0·061	054	1·455	298	0·026	177	0·990	294
(40)	0·030	096	1·245	053	0·033	003	1·001	137

TABLE 8.—*Harmonic Shallow Water Correction Constants*
(Combined 1st and 2nd approximations)

Place : KIDDERPORE
Central day of analysis : 1st July 1948

Based on : Saugor basic predictions
Derived from : (A—P)s of 1948

Constituent	H.W. heights		H.W. times		L.W. heights		L.W. times	
	R	χ	R	χ	R	χ	R	χ
	ft.	°	*min.*	°	*ft.*	°	*min.*	°
C (00)	+0·006	..	−3·58	..	−0·010	..	−8·47	..
(01)	0·097	207	21·60	317	0·037	325	14·08	300
(02)	0·143	015	10·31	211	0·064	063	6·18	302
(11)	0·022	270	2·67	193	0·123	286	3·18	189
(13)	0·135	085	1·59	150	0·358	011	6·48	009
(25)	0·286	085	6·90	221	1·138	036	30·30	035
(27)	0·168	044	1·91	324	0·455	035	11·70	044
(36)	0·099	200	5·38	050	0·036	138	3·46	033
(38)	0·062	066	1·96	130	0·204	054	4·60	077
(50)	0·157	104	2·30	242	0·116	264	6·30	242
(52)	0·091	066	1·14	218	0·095	323	7·25	266
C′ (00)	+0·001	..	+1·23	..	+0·021	..	+1·12	..
(11)	0·031	335	1·03	305	0·022	090	1·89	179
(12)	0·046	299	3·19	176	0·019	155	0·88	042
(13)	0·033	230	4·98	117	0·133	033	5·50	059
(27)	0·006	239	1·04	154	0·042	052	0·42	287
(36)	0·124	139	4·23	356	0·081	281	3·32	282
(38)	0·050	251	2·06	169	0·021	197	1·05	179
(40)	0·047	277	0·44	171	0·082	228	3·93	306

TABLE 9.—*Corrections applied to the predicted times and heights at Bhāvnagar for 1953*

Month	H.W. Time min.	H.W. Height ft.	L.W. Time min.	L.W. Height ft.
January ..	−10	+0·4	+50	See Table 10
February ..		+0·4		
March ..		+0·5		
April ..		+0·6		
May ..		+0·3		
June ..		+0·4		
July ..		+0·4		
August ..		+1·0		
September ..		+0·8		
October ..		+0·6		
November ..		+0·4	+40	
December ..		+0·2	+40	

TABLE 10.—*Corrections applied to the predicted heights of L.W. at Bhāvnagar for 1953*

Predicted height in feet	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
	Corrections in feet									
0	5·9	5·8	5·8	5·7	5·6	5·6	5·5	5·4	5·3	5·3
1	5·2	5·2	5·1	5·0	4·9	4·9	4·8	4·7	4·7	4·6
2	4·5	4·4	4·3	4·2	4·1	4·1	4·0	3·9	3·8	3·8
3	3·7	3·6	3·5	3·5	3·4	3·3	3·2	3·2	3·1	3·1
4	3·0	2·9	2·8	2·7	2·6	2·5	2·5	2·4	2·4	2·3
5	2·3	2·2	2·1	2·0	1·9	1·9	1·8	1·8	1·7	1·7
6	1·6	1·6	1·5	1·5	1·4	1·4	1·3	1·3	1·2	1·1
7	1·1	1·1	1·0	1·0	0·9	0·9	0·8	0·8	0·8	0·7
8	0·7	0·7	0·6	0·6	0·6	0·5	0·5	0·5	0·5	0·4
9	0·4	0·4	0·3	0·3	0·3	0·2	0·2	0·2	0·2	0·1
10	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·1	0·0	0·0
11	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0
12	0·0	0·0	0·0	0·0	−0·1	−0·1	−0·1	−0·1	−0·1	−0·1
13	−0·1	−0·1	−0·1	−0·1	−0·1	−0·2	−0·2	−0·2	−0·2	−0·2
14 and above	−0·2	−0·2	−0·2	−0·2	−0·2	−0·2	−0·2	−0·2	−0·2	−0·2

TABLE 11.—*Corrections applied to the predicted times and heights at Rangoon for 1953*

Month	H.W.		L.W.	
	Time	Height	Time	Height
	min.	*ft.*	*min.*	*ft.*
January ..	− 19	+ 0·1	0	0·0
February ..	− 15	+ 0·1	− 1	− 0·1
March ..	− 14	+ 0·2	− 6	− 0·2
April ..	− 13	+ 0·2	− 12	− 0·2
May ..	− 15	+ 0·2	− 16	− 0·1
June ..	− 18	+ 0·3	− 22	+ 0·2
July ..	− 22	+ 0·3	− 26	− 0·1
August ..	− 26	+ 0·2	− 21	− 0·3
September ..	− 25	+ 0·1	− 15	− 0·5
October ..	− 22	+ 0·1	− 8	− 0·2
November ..	− 18	+ 0·1	− 2	0·0
December ..	− 15	0·0	+ 5	− 0·1

TABLE 12.—*Mean errors E_1* and E_2* for 1950*

ADEN

PERIOD 1950	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E_1								E_2				30 *minutes* in time		0·7† *feet* in height	
	H.W. Time		H.W. Height		L.W. Time		L.W. Height		H.W. Time	H.W. Ht.	L.W. Time	L.W. Ht.	H.W.	L.W.	H.W.	L.W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1-15		8·8		0·1		2·7		0·0	13·5	0·2	9·5	0·1	0	0	0	0
16-31		0·4		0·3	4·9			0·2	11·3	0·3	10·4	0·2	3	0	0	0
Feb. 1-15		10·0		0·3		2·9		0·1	14·3	0·3	9·1	0·2	2	0	0	0
16-28		2·6		0·1		2·8		0·0	16·0	0·2	10·6	0·2	0	1	0	0
Mar. 1-15		4·3	0·2			5·1	0·3		12·6	0·2	10·3	0·4	2	1	0	0
16-31		7·9	0·2			1·1	0·3		17·5	0·3	15·0	0·3	2	2	0	0
April 1-15	0·4		0·0			0·6	0·2		12·6	0·1	8·6	0·3	2	0	0	0
16-30		2·6	0·0		0·5		0·1		11·3	0·3	16·0	0·3	1	3	0	0
May 1-15		5·7		0·3		5·6		0·1	10·9	0·3	10·7	0·3	0	0	0	0
16-31	2·8		0·0			7·9	0·1		11·5	0·1	12·5	0·2	3	1	0	0
June 1-15	4·2			0·3	1·3			0·3	12·2	0·3	13·7	0·3	0	3	0	0
16-30	4·6			0·4	2·8			0·3	16·1	0·4	13·8	0·3	3	2	0	0
July 1-15	3·8			0·4	9·1			0·4	12·9	0·4	15·8	0·4	1	2	0	0
16-31		1·0		0·2		0·2		0·1	12·5	0·2	13·0	0·2	1	0	0	0
Aug. 1-15		1·7		0·2	2·6			0·2	11·8	0·3	10·9	0·2	1	0	0	0
16-31	1·4			0·5	10·7			0·3	11·0	0·5	12·4	0·4	0	0	0	0
Sept. 1-15	9·4			0·4	17·2			0·3	13·6	0·4	17·3	0·3	4	2	0	0
16-30	0·7			0·1	6·7			0·0	11·4	0·2	12·4	0·1	1	2	0	0
Oct. 1-15	3·2			0·2	5·3			0·2	9·6	0·2	12·6	0·3	0	1	0	0
16-31		2·4	0·3		0·3		0·4		8·2	0·3	13·2	0·4	0	1	0	1
Nov. 1-15	6·3		0·3		3·8		0·3		12·6	0·3	9·2	0·4	1	0	0	0
16-30	8·5		0·2		4·1		0·2		16·9	0·2	14·9	0·2	3	2	0	0
Dec. 1-15	11·4			0·1	12·0			0·1	13·1	0·2	14·6	0·2	1	2	0	0
16-31	5·0			0·2	5·8			0·1	15·8	0·2	12·7	0·1	3	0	0	0
TOTALS ..	61·7	47·4	1·2	4·1	89·1	28·9	1·9	2·7	309·2	6·4	299·2	6·3	34	25	0	1
MEANS ..	+ 0·6		− 0·1		+ 2·5		− 0·0		12·9	0·3	12·5	0·3				

* E_1 is with regard to sign : E_2 is without regard to sign.
† One-tenth of the mean range of the ordinary spring-tides.

TABLE 13.—*Mean errors E_1* and E_2* for 1950*

BHAVNAGAR

PERIOD 1950	MEAN ERRORS (Predicted – Actual†)												Number of errors exceeding			
	E_1								E_2				30 *minutes* in time		1·0‡ *feet* in height	
	H.W.				L.W.				H.W.		L.W.					
	Time		Height		Time		Height		Time	Ht.	Time	Ht.	H.W.	L.W.	H.W.	L.W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	–	+	–	+	–	+	–								
Jan. 1–15	5·7			0·2		0·5	0·3		9·7	0·6	11·2	0·4	0	0	1	1
16–31	4·7		0·2			1·5		0·3	6·6	0·5	19·2	0·5	0	3	1	0
Feb. 1–15	0·4		0·1			0·0		0·1	6·0	0·4	20·3	0·5	0	2	0	0
16–28		1·9	0·5			11·2	0·5		6·7	0·6	23·0	0·6	0	4	2	2
Mar. 1–15		2·6		0·1	2·2		0·6		9·9	0·7	15·9	0·7	1	2	5	1
16–31	4·4		0·4			6·2	0·5		8·1	0·7	18·0	0·6	0	2	4	2
April 1–15	0·9			0·1		6·3	0·0		7·0	0·7	16·1	0·2	0	0	3	0
16–30		3·3	0·2			13·3	0·5		9·0	0·5	19·5	0·6	0	1	0	1
May 1–15	1·7			0·3		10·6	0·2		7·2	0·7	15·8	0·4	0	4	2	0
16–31	1·4		0·3			3·4	0·4		7·7	0·5	9·8	0·5	0	0	0	1
June 1–15	0·5			0·1	2·7			0·2	4·6	0·6	10·3	0·4	0	1	0	1
16–30	3·8			0·1	3·7		0·1		7·5	0·6	8·3	0·4	0	0	1	1
July 1–15	5·2		0·2		5·0			0·8	7·2	0·5	7·3	1·4	0	0	1	6
16–31	10·3			0·6	4·4			1·6	11·6	0·6	7·8	1·6	0	0	1	11
Aug. 1–15	3·9		0·1		4·3			0·2	7·2	0·4	10·8	0·6	0	1	1	2
16–31	4·9		0·4		2·3			0·1	6·9	0·4	12·3	0·7	0	1	0	2
Sept. 1–15	1·3		0·3		2·5		0·1		5·3	0·4	8·4	0·4	0	0	0	0
16–30	4·0			0·1	7·8			0·1	5·9	0·6	11·5	0·4	0	1	2	1
Oct. 1–15	6·4		0·3		6·0			0·1	7·9	0·3	10·7	0·4	0	1	0	0
16–31	3·5		0·4		6·0			0·1	5·6	0·4	8·3	0·3	0	0	0	0
Nov. 1–15	2·9		0·4		13·4			0·1	4·7	0·4	14·2	0·3	0	2	0	0
16–30	1·1		0·0		8·3		0·2		4·7	0·4	10·1	0·4	0	1	0	0
Dec. 1–15		3·7	0·1			2·7		0·7	4·1	0·4	2·7	0·7	0	0	1	3
16–31		3·6	0·5			3·3		0·1	3·6	0·7	3·3	0·6	0	0	5	4
TOTALS ..	67·0	15·1	4·4	1·6	68·6	59·0	3·4	4·5	164·7	12·6	294·8	13·6	1	26	30	39
MEANS ..	+ 2·2		+ 0·1		+ 0·4		– 0·0		6·9	0·5	12·3	0·6				

* E_1 is with regard to sign : E_2 is without regard to sign.
† Actual values are tide-pole readings during daylight only.
‡ One-tenth of the mean range of the ordinary spring-tides is 3·1 feet.

TABLE 14.—*Mean errors E_1* and E_2* for 1950*

BOMBAY (APOLLO BANDAR)

PERIOD 1950	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E_1								E_2				30 *minutes* in time		1·0† *feet* in height	
	H.W. Time		H.W. Height		L.W. Time		L.W. Height		H.W. Time	H.W. Ht.	L.W. Time	L.W. Ht.	H.W.	L.W.	H.W.	L.W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	–	+	–	+	–	+	–								
Jan. 1–15		1·1	0·0		2·8		0·2		9·6	0·3	8·3	0·3	0	1	0	0
16–31		5·8	0·1			7·1	0·2		12·1	0·2	10·6	0·3	2	1	0	0
Feb. 1–15	0·9		0·2		0·1		0·4		5·1	0·3	8·6	0·4	0	0	0	2
16–28		1·4	0·3			1·8	0·4		10·0	0·3	8·6	0·5	3	1	0	2
Mar. 1–15	2·0			0·1	2·1		0·0		7·4	0·3	7·7	0·3	0	0	0	0
16–31		1·5		0·2		2·2	0·2		10·3	0·3	9·8	0·3	0	1	0	0
April 1–15	4·6			0·4	8·3			0·1	11·6	0·4	12·2	0·4	1	1	0	2
16–30	7·1			0·2	10·3		0·2		13·0	0·3	11·3	0·4	3	4	0	0
May 1–15	3·8			0·0		1·0	0·1		10·9	0·4	7·3	0·3	0	0	0	0
16–31	5·6		0·1		4·9		0·4		9·7	0·3	10·8	0·4	0	0	0	1
June 1–15	2·4		0·1			2·1	0·0		7·0	0·3	7·5	0·3	0	0	1	0
16–30	7·0		0·1		18·3		0·3		10·7	0·3	18·3	0·3	2	2	0	0
July 1–15		6·4	0·3			1·0	0·2		13·5	0·4	15·1	0·4	2	1	2	0
16–31		2·5		0·3	9·5			0·2	12·6	0·4	12·6	0·4	0	0	0	0
Aug. 1–15		5·9		0·1	5·0			0·2	12·4	0·2	13·2	0·3	0	2	0	0
16–31	0·5		0·4		5·4		0·3		8·4	0·4	10·1	0·4	0	0	2	1
Sept. 1–15		0·2	0·1		2·3		0·1		14·5	0·2	11·3	0·3	2	2	0	0
16–30	3·7		0·3		7·2		0·0		8·9	0·4	13·8	0·3	1	3	0	0
Oct. 1–15		0·4	0·0		5·8		0·2		9·7	0·2	12·1	0·2	1	2	0	0
16–31	2·4		0·2		5·5		0·2		6·9	0·3	8·8	0·2	0	0	1	0
Nov. 1–15		4·5	0·3		1·2		0·3		10·3	0·3	10·2	0·4	1	1	0	0
16–30	2·5		0·0			2·6	0·2		9·3	0·2	7·0	0·3	0	0	0	0
Dec. 1–15	0·2		0·1			2·2	0·0		8·4	0·3	7·2	0·3	1	0	0	0
16–31		3·9	0·1			10·5	0·3		10·2	0·3	11·8	0·3	0	0	0	0
TOTALS ..	42·7	33·6	2·7	1·3	89·6	31·4	4·2	0·5	242·5	7·3	254·2	8·0	19	22	6	8
MEANS ..	+ 0·4		+ 0·1		+ 2·4		+ 0·2		10·1	0·3	10·6	0·3				

* E_1 is with regard to sign : E_2 is without regard to sign.
† One-tenth of the mean range of the ordinary spring-tides is 1·4 feet.

TABLE 15.—*Mean errors E_1* and E_2* for 1950*

VIZAGAPATAM

PERIOD 1950	MEAN ERRORS (Predicted – Actual)												Number of errors exceeding			
	E_1								E_2				30 *minutes* in time		0·5† *feet* in height	
	H.W. Time		H.W. Height		L.W. Time		L.W. Height		H.W. Time	H.W. Ht.	L.W. Time	L.W. Ht.	H.W.	L.W.	H.W.	L.W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	–	+	–	+	–	+	–								
Jan. 1–15	1·2			0·1	3·0		0·1		2·8	0·3	3·3	0·2	0	0	0	2
16–31	1·6			0·1	2·0		0·1		3·8	0·1	2·9	0·1	2	0	0	0
Feb. 1–15	1·0			0·2	1·3			0·1	1·0	0·2	1·7	0·1	0	0	0	0
16–28	2·7			0·2	0·8			0·1	2·7	0·2	2·1	0·2	0	1	0	0
Mar. 1–15	1·7			0·3	2·1			0·2	1·7	0·3	3·0	0·2	0	0	0	0
16–31	1·4			0·3	1·8			0·1	2·7	0·3	3·0	0·2	0	0	1	0
April 1–15	1·2			0·4	3·2			0·1	1·2	0·4	3·6	0·2	0	0	4	0
16–30	0·9			0·2	1·7			0·0	0·9	0·2	1·7	0·2	0	0	1	0
May 1–15	1·0			0·3	2·1			0·0	2·9	0·3	2·1	0·1	0	0	0	0
16–31	3·6			0·6	0·6			0·2	3 6	0·6	0·6	0·4	0	0	13	8
June 1–15	0·9			0·6		0·8		0·5	1·4	0·6	2·6	0·5	0	0	16	12
16–30	0·6			0·6	0·7			0·2	0·6	0·6	0·7	0·2	0	0	17	1
July 1–15	2·9			0·5	0·4			0·2	2·9	0·5	0·4	0·2	0	0	9	2
16–31	3·9			0·3	2·7		0·1		3·9	0·3	2·7	0·2	0	0	0	2
Aug. 1–15	4·8		0·3		1·8		0·5		5·5	0·3	1·8	0·5	0	0	0	9
16–31	2·3			0·1	5·8		0·3		3·6	0·1	6·3	0·3	0	1	0	1
Sept. 1–15	0·5			0·6	1·3			0·3	1·6	0·6	2·4	0·4	0	0	12	10
16–30	0·3			0·3	2·2			0·1	0·4	0·3	2·2	0·2	0	0	3	2
Oct. 1–15	0·2			0·1	0·0		0·1		1·7	0·2	1·4	0·1	0	0	0	0
16–31	·	1·0		0·5		0·4		0·1	3·9	0·5	1·7	0·2	0	0	9	0
Nov. 1–15	·	3·9		0·4		1·1		0·0	6·2	0·4	1·1	0·2	1	0	6	0
16–30	·	1·6		0·3	0·9			0·0	3·8	0·4	1·6	0·4	0	0	8	4
Dec. 1–15	2·0			0·5	0·5			0·2	2·0	0·5	2·6	0·3	0	0	11	3
16–31	1·5			0·1	1·4		0·1		2·7	0·2	3·1	0·2	0	0	0	0
TOTALS ..	36·2	6·5	0·3	7·6	36·3	2·3	1·3	2·4	63·5	8·4	54·6	5·8	3	2	110	56
MEANS ..	+ 1·2		– 0·3		+ 1·4		– 0·0		2·6	0·4	2·3	0·2				

* E_1 is with regard to sign: E_2 is without regard to sign.
† One-tenth of the mean range of the ordinary spring-tides.

TABLE 16.—*Mean errors E_1* and E_2* for 1950*

SAUGOR (DUBLAT)

PERIOD 1950	MEAN ERRORS† (Predicted – Actual) E_1 H.W. Time (minutes) +	–	H.W. Height (feet) +	–	L.W. Time (minutes) +	–	L.W. Height (feet) +	–	E_2 H.W. Time (minutes)	H.W. Ht. (feet)	L.W. Time (minutes)	L.W. Ht. (feet)	Number of errors exceeding 30 minutes in time H.W.	30 minutes in time L.W.	1·0‡ feet in height H.W.	1·0‡ feet in height L.W.
Jan. 1-15		4·7		0·1		5·2	0·1		6·3	0·3	6·9	0·3	0	0	0	0
16-31		0·8		0·2	0·9		0·0		8·9	0·3	8·3	0·3	1	0	0	0
Feb. 1-15		3·4		0·0		4·5	0·0		8·3	0·2	7·7	0·5	0	0	0	1
16-28	8·9			0·1	8·8		0·3		16·5	0·2	14·2	0·5	4	4	0	1
Mar. 1-15		13·0		0·0		10·4		0·1	14·6	0·3	12·4	0·4	2	1	0	2
16-31		7·6		0·1		2·8	0·3		13·3	0·3	11·4	0·4	3	2	0	0
April 1-15		17·2		0·3		10·8		0·5	17·2	0·5	13·6	0·5	3	0	4	3
16-30	0·6			0·7		0·1		0·2	8·4	0·7	11·4	0·4	0	2	4	0
May 1-15		8·8		0·1		11·4		0·2	10·8	0·3	16·6	0·3	0	4	0	0
16-31	0·5			0·3		1·3		0·1	6·4	0·4	9·1	0·5	0	1	1	1
June 1-15		4·1		0·2		4·7		0·4	8·2	0·4	10·2	0·6	1	0	1	1
16-30		2·7		0·0		1·4		0·0	6·4	0·3	7·3	0·4	0	0	0	0
July 1-15		1·3		0·2	4·2			0·3	8·1	0·4	9·5	0·4	0	1	1	4
16-31		7·8	0·1			9·8		0·0	10·2	0·4	10·6	0·4	0	0	2	0
Aug. 1-15		6·2	0·5			5·4	0·6		11·2	0·6	9·7	0·6	0	0	5	3
16-31		10·7	0·1			9·7	0·0		12·5	0·3	11·5	0·3	0	2	1	0
Sept. 1-15	5·3			0·5	11·1			0·5	14·9	0·5	15·3	0·6	5	6	1	7
16-30		4·4		0·1		3·3		0·2	7·2	0·3	8·2	0·4	0	0	0	0
Oct. 1-15		1·6		0·4	3·3			0·2	14·9	0·4	20·5	0·6	3	6	1	3
16-31		5·0		0·2		4·1		0·3	6·8	0·3	7·6	0·3	1	0	2	0
Nov. 1-15		4·7		0·3		7·2		0·4	11·6	0·4	13·7	0·4	0	0	2	0
16-30		2·4		0·4		4·9		0·1	6·9	0·5	10·0	0·6	1	0	4	3
Dec. 1-15		4·1		0·5		4·3		0·7	9·2	0·6	10·1	0·7	0	1	6	5
16-31	2·8			0·3	3·0		0·1		6·1	0·4	7·9	0·5	0	0	1	0
TOTALS ..	17·6	110·5	0·7	5·0	31·3	101·3	1·4	4·2	244·9	9·3	263·7	10·9	24	30	36	34
MEANS ..	—	3·9	—	0·2	—	2·9	—	0·1	10·2	0·4	11·0	0·5				

* E_1 is with regard to sign : E_2 is without regard to sign.

† Corrected for the effects of faulty tide-gauge settings, caused by B.M. subsidence and datum s.

‡ One-tenth of the mean range of the ordinary spring-tides is 1·4 feet.

TABLE 17.—*Mean errors E_1* and E_2* for 1950*

DIAMOND HARBOUR

PERIOD 1950	MEAN ERRORS† (Predicted – Actual)												Number of errors exceeding			
	E_1								E_2				30 *minutes* in time		1·0‡ *feet* in height	
	H.W. Time		H.W. Height		L.W. Time		L.W. Height		H.W. Time	H.W. Ht.	L.W. Time	L.W. Ht.	H.W.	L.W.	H.W.	L.W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1–15		7·1	0·6		1·0		0·6		11·3	0·6	10·1	0·7	0	1	7	7
16–31		3·0	0·0		15·6		0·3		12·5	0·4	15·6	0·5	2	4	1	3
Feb. 1–15		7·8	0·4			0·4	0·4		11·8	0·5	9·0	0·6	0	0	3	6
16–28	0·8		0·0		20·6		0·5		15·1	0·3	22·1	0·6	2	5	0	2
Mar. 1–15		9·9	0·3			1·8	0·2		14·4	0·6	10·9	0·4	1	1	4	3
16–31		5·4	0·4		12·8		0·6		16·2	0·5	16·9	0·6	5	4	1	5
April 1–15		13·6	0·2			5·2		0·1	16·1	0·8	14·0	0·4	3	1	8	0
16–30		3·9		0·5	16·3		0·0		10·7	0·5	21·6	0·5	1	6	4	1
May 1–15		14·0	0·0			3·6	0·3		16·8	0·4	16·4	0·4	4	4	0	0
16–31		8·6		0·1		8·8	0·4		10·3	0·5	15·6	0·4	2	3	2	1
June 1–15		9·1		0·2		7·4	0·6		15·3	0·5	15·2	0·4	1	0	0	1
16–30		2·9		0·1	7·2		0·2		9·1	0·4	12·4	0·5	0	1	2	2
July 1–15	2·0			0·2	22·9			0·1	12·2	0·5	22·9	0·5	0	7	4	2
16–31		4·2	0·2		4·5		0·2		12·1	0·5	9·0	0·5	2	0	5	2
Aug. 1–15	0·3		0·3		11·0		0·1		11·2	0·5	13·4	0·3	2	2	4	2
16–31		9·2	0·7			1·8	0·4		10·5	0·8	13·5	0·5	0	1	7	2
Sept. 1–15	7·9			0·2	28·3			0·3	16·1	0·5	29·7	0·5	4	12	3	3
16–30		3·3	0·2		8·1			0·1	8·5	0·5	9·1	0·4	0	0	0	0
Oct. 1–15		0·6		0·0	10·1		0·2		13·0	0·4	18·6	0·6	3	5	2	3
16–31		8·6	0·3		10·5		0·2		10·6	0·6	14·8	0·3	0	5	4	0
Nov. 1–15		2·3	0·1		5·2			0·0	11·1	0·6	15·9	0·4	1	6	6	0
16–30		5·5		0·1	13·2			0·0	10·2	0·5	14·8	0·6	1	0	3	7
Dec. 1–15		6·6		0·1	7·6			0·3	12·8	0·6	13·4	0·7	1	1	5	5
16–31		5·1		0·0	14·7		0·3		10·2	0·4	15·3	0·6	0	0	0	6
TOTALS ..	11·0	130·7	3·7	1·5	209·6	29·0	5·5	0·9	298·1	12·4	370·2	11·9	35	69	75	63
MEANS ..	− 5·0		+ 0·1		+ 7·5		+ 0·2		12·4	0·5	15·4	0·5				

* E_1 is with regard to sign : E_2 is without regard to sign.

† Corrected for the effects of faulty tide-gauge settings, caused by B.M. subsidence and datum changes.

‡ One-tenth of the mean range of the ordinary spring-tides is 1·6 feet.

TABLE 18.—*Mean errors E_1* and E_2* for 1950*

CALCUTTA (KIDDERPORE)

PERIOD 1950	MEAN ERRORS† (Predicted — Actual)												Number of errors exceeding			
	E_1								E_2				30 *minutes* in time		1·0‡ *feet* in height	
	H.W. Time		H.W. Height		L.W. Time		L.W. Height		H.W. Time	H.W. Ht.	L.W. Time	L.W. Ht.	H.W.	L.W.	H.W.	L.W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1–15		6·2		0·1		1·6	0·2		11·2	0·3	10·3	0·4	0	0	0	4
16–31	2·5			0·5	12·1			0·0	11·4	0·6	13·9	0·5	1	6	3	1
Feb. 1–15		1·0		0·2		2·6	0·2		12·6	0·4	8·6	0·6	0	0	2	5
16–28	8·6			0·3	18·8		0·1		16·0	0·3	19·3	0·4	3	5	0	1
Mar. 1–15		9·1		0·1		8·7	0·3		12·1	0·4	12·2	0·6	0	1	0	1
16–31		7·6	0·1		4·9		0·4		18·4	0·4	15·0	0·5	1	4	1	1
April 1–15		9·1		0·2		4·9	0·0		15·6	0·5	13·1	0·4	1	0	2	1
16–30	5·2			0·7	15·6			0·3	10·5	0·7	19·2	0·4	0	7	6	0
May 1–15		8·8		0·1		8·1	0·2		10·2	0·6	15·4	0·4	0	3	3	0
16–31		5·3		0·0	1·3		0·3		11·3	0·4	13·0	0·3	0	0	1	0
June 1–15	1·0			1·0	0·7			0·5	13·9	1·1	21·4	0·7	1	3	15	6
16–30	0·8			1·0		3·5		0·2	11·9	1·0	9·8	0·3	0	0	13	0
July 1–15	3·8			1·3	12·1			0·5	9·4	1·3	15·8	0·6	0	2	18	4
16–31	1·1			0·7		9·4	0·5		11·3	0·7	12·8	0·6	0	0	9	6
Aug. 1–15	7·0			0·6	6·0			0·3	14·7	0·7	16·3	0·6	2	4	10	5
16–31		3·8		0·5		11·4	0·1		10·7	0·6	13·6	0·3	0	2	2	0
Sept. 1–15	13·1			0·1	18·7		0·1		17·6	0·4	21·5	0·4	3	6	2	1
16–30		1·4	0·5			0·4	0·6		8·9	0·5	7·1	0·6	0	0	3	6
Oct. 1–15		2·1	0·8		5·1		1·4		11·9	0·9	21·1	1·4	3	6	7	22
16–31		12·9	0·9		0·1		1·3		16·1	1·0	11·8	1·3	4	1	18	22
Nov. 1–15		5·4		0·1		3·2	0·6		11·9	0·4	21·3	0·7	1	7	3	8
16–30		2·4		0·5	5·3			0·3	10·6	0·6	9·6	0·5	0	1	5	1
Dec. 1–15	0·6			0·7		2·0		0·1	13·4	0·8	14·6	0·5	0	2	9	2
16–31		2·3		0·4	7·8			0·2	12·1	0·5	11·3	0·5	1	1	3	0
TOTALS ..	43·7	77·4	2·3	9·1	117·5	55·8	6·3	2·4	303·7	15·1	348·0	13·5	21	61	135	97
MEANS ..	−	1·4	−	0·3	+	2·6	+	0·2	12·7	0·6	14·5	0·6				

* E_1 is with regard to sign : E_2 is without regard to sign.

† Corrected for the effects of faulty tide-gauge settings, caused by B.M. subsidence and datum nges.

‡ One-tenth of the mean range of the ordinary spring-tides is 1·2 feet.

TABLE 19.—*Mean errors E_1* and E_2* for 1950*

RANGOON

PERIOD 1950	MEAN ERRORS (Predicted—Actual)												Number of errors exceeding			
	E_1								E_2				30 *minutes* in time		1·0† *feet* in height	
	H.W. Time		H.W. Height		L.W. Time		L.W. Height		H.W. Time	H.W. Ht.	L.W. Time	L.W. Ht.	H.W.	L.W.	H.W.	L.W.
	minutes		*feet*		*minutes*		*feet*		*minutes*	*feet*	*minutes*	*feet*				
	+	−	+	−	+	−	+	−								
Jan. 1–15	0·9			0·3		13·9		0·3	6·7	0·4	13·9	0·3	0	0	0	0
16–31	3·3			0·2	0·1			0·8	9·9	0·4	13·0	0·8	0	1	0	2
Feb. 1–15		3·8		0·1		12·5		0·4	8·2	0·2	13·1	0·5	0	0	0	1
16–28		0·2		0·2	9·0			0·6	13·0	0·3	17·4	0·6	2	2	0	1
Mar. 1–15		5·1		0·1		13·2		0·5	9·6	0·3	13·5	0·5	1	0	0	1
16–31	1·8			0·3	5·3			0·3	10·4	0·5	18·4	0·5	0	2	1	2
April 1–15		8·1		0·2		7·5		0·7	9·5	0·4	9·9	0·7	2	0	1	2
16–30		3·7		0·4	13·3			0·3	7·7	0·4	18·7	0·6	0	4	0	2
May 1–15		9·9	0·3			3·5		0·0	10·5	0·3	11·1	0·5	1	0	0	1
16–31	0·6			0·4	13·2		0·1		8·1	0·4	18·8	0·8	0	3	0	4
June 1–15		3·0	0·2		7·0			0·1	7·9	0·3	10·2	0·7	0	0	0	3
16–30		4·0		0·1	10·1		0·3		8·8	0·3	10·7	0·7	0	0	0	3
July 1–15	0·9			0·1	19·9		0·1		5·3	0·4	19·9	0·6	0	3	0	2
16–31		4·6		0·1	7·1		0·5		6·3	0·2	9·6	0·6	0	0	0	3
Aug. 1–15		3·5		0·0	17·4		0·5		5·7	0·6	17·5	0·7	0	1	1	4
16–31		0·9	0·2		2·2		0·7		4·1	0·4	8·2	0·7	0	0	0	1
Sept. 1–15	9·4			0·2	9·3			0·4	12·8	0·5	10·9	0·5	2	1	1	2
16–30	6·5			0·2		0·5		0·0	9·1	0·5	6·0	0·4	0	0	0	1
Oct. 1–15	7·9			0·2	4·7			0·5	11·4	0·4	14·9	0·7	0	1	0	2
16–31		1·2		0·4		4·1		0·0	5·5	0·6	6·9	0·3	0	0	3	0
Nov. 1–15	8·8			0·3		3·1		1·0	8·8	0·4	18·3	1·0	1	2	0	6
16–30		0·3		0·4		3·0		0·5	7·8	0·6	7·0	0·5	0	0	5	1
Dec. 1–15	11·1			0·5		9·2		1·5	11·6	0·5	13·7	1·5	0	0	1	11
16–31	1·9			0·3		5·1		0·5	8·2	0·4	8·8	0·5	0	0	0	2
TOTALS ..	53·1	48·3	0·7	5·0	118·6	75·6	2·2	8·4	206·9	9·7	310·4	15·2	9	20	13	57
MEANS ..	+	0·2	−	0·2	+	1·8	−	0·2	8·6	0·4	12·9	0·6				

* E_1 is with regard to sign: E_2 is without regard to sign.
† One-tenth of the mean range of the ordinary spring-tides is 1·6 feet.

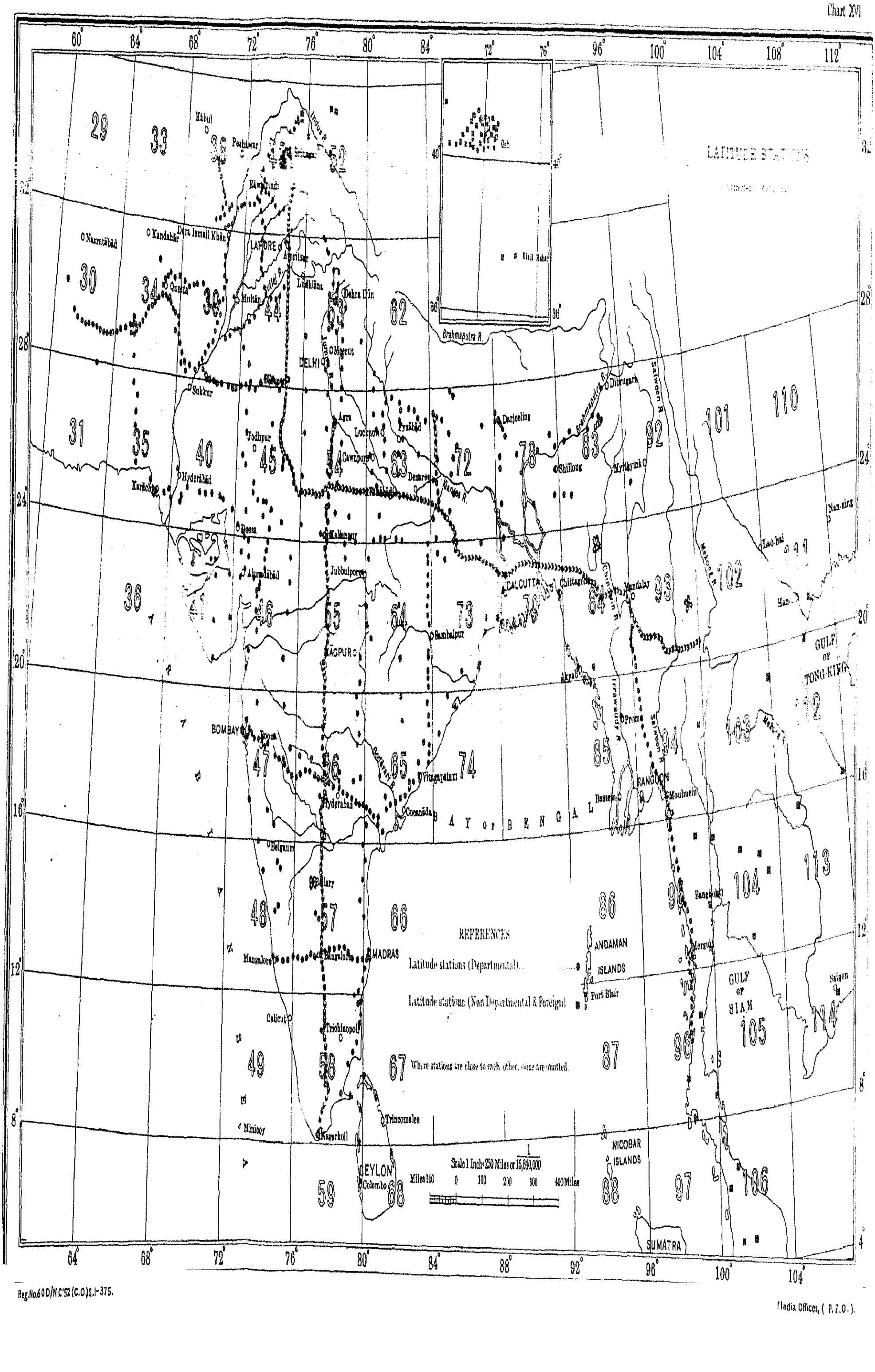
TABLE 20.—*Greatest differences between the predicted and actual heights of Low Water during 1950*

Port	Predicted *minus* actual	Date	REMARKS
Aden ..	*feet* + 1·4	31st October	
Bhāvnagar ..	− 4·5	14th July	A bar has formed in the channel which obstructs the flow of water to the tide-pole, thereby affecting all tides below 9 ft. The mean range of the ordinary spring tides at this port is 31·5 ft.
Bombay (Apollo Bandar)	+ 1·2	16th February 30th May	
Vizagapatam ..	− 0·9	27th to 30th May, 11th June, 10th to 12th September	
Calcutta (Kidderpore)	+ 3·1	15th October	Riverain port.
Saugor ..	− 2·3	13th to 15th September and 8th December	Do.
Diamond Harbour ..	− 4·1	12th June	Do.
Rangoon ..	− 3·4	6th December	Do.

TABLE 21.—*Accuracy Statement of H.S.W. predictions and old Riverain predictions*

Serial No.	Name of port and year of comparison	Method of predictions		Times: Correct within (*minutes*) 5	10	15	20	25	30	Heights: Correct within (*feet*) 0·5	1·0
				%	%	%	%	%	%	%	%
1	Saugor 1948*	H.W.	Old (with empirical corrections)	42	69	84	90	92	94	65	88
			H.S.W. method	50	75	90	95	98	99	91	100
		L.W.	Old (with empirical corrections)	37	66	83	90	94	96	59	88
			H.S.W. method	44	74	89	94	97	98	85	100
2	Diamond Harbour 1948*	H.W.	Old	28	49	70	82	90	95	46	76
			H.S.W. method	34	61	78	92	96	98	81	98
		L.W.	Old	25	47	62	77	86	93	36	74
			H.S.W. method	39	67	82	91	97	98	85	99
3	Kidderpore 1948†	H.W.	Old (with empirical corrections)	39	60	76	84	94	98	80	98
			H.S.W. method	41	68	83	91	98	100	79	100
		L.W.	Old (with empirical corrections)	32	51	70	86	94	99	53	92
			H.S.W. method	38	64	85	93	97	100	85	100
4	Rangoon 1941‡	H.W.	Old (with empirical corrections)	Not computed						68	85
			H.S.W. method							90	100
		L.W.	Old (with empirical corrections)							33	67
			H.S.W. method							62	88

* Percentages from the results of verification for a period of 1 year.
† Percentages from the results of verification for a period of 3 months.
‡ Percentages from the results of verification for a period of 1 month.



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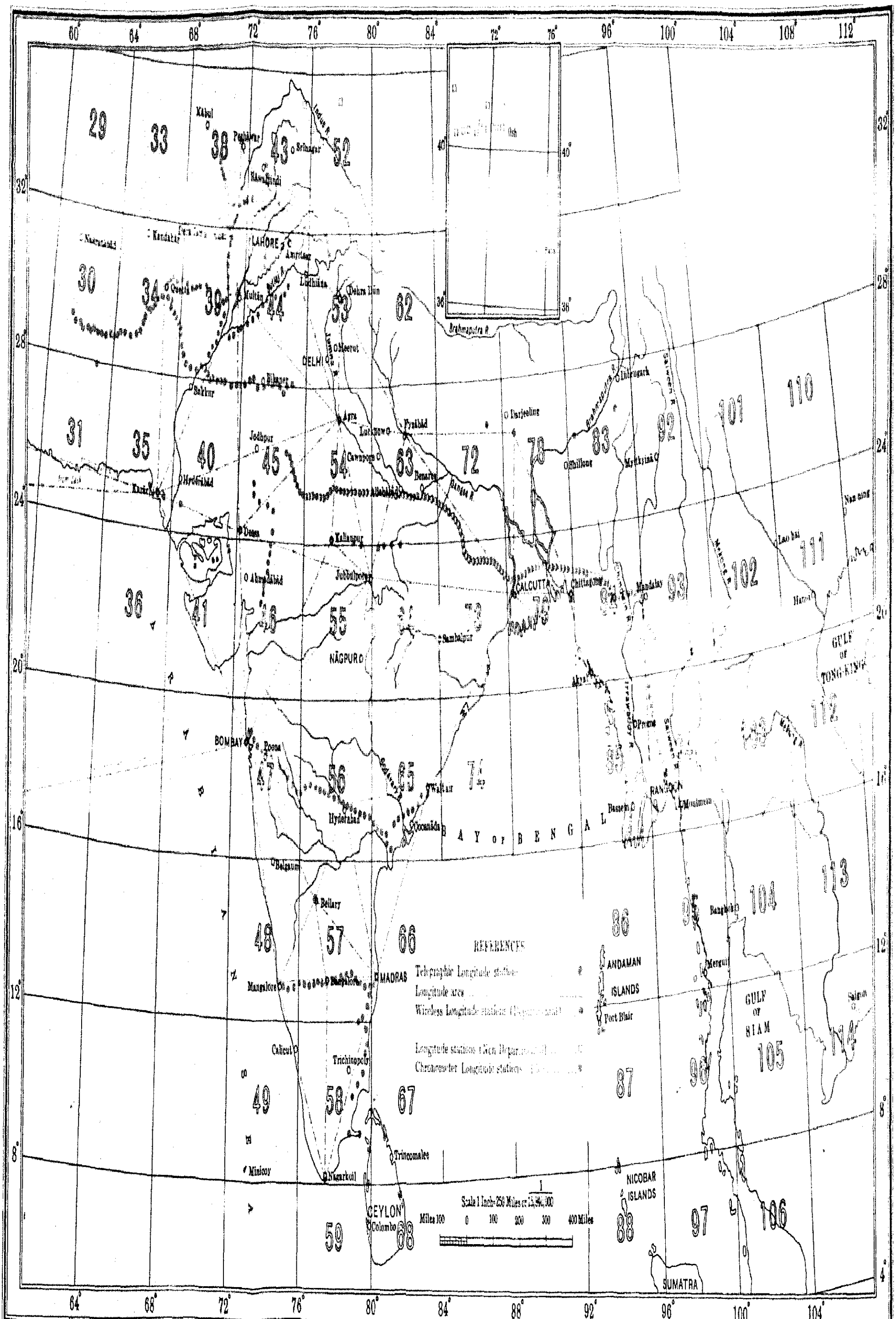

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CHAPTER V

DEVIATION OF THE VERTICAL

BY B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

45. **General.**—The season's field work consisted of establishing an astronomical datum for the geodetic triangulation of the Andamans, and the observation of a meridional section of the geoid along longitude 73° 45′ from Tiki near Udaipur to Pāvāgad near Baroda the existing section being weak. Laplace observations were made at a pair of stations of this meridional geoidal section. In the Andamans, observations for both components of the deviation of the vertical and azimuth by Polaris were taken at two other stations also.

Observations in all cases were made with a large 60-degree prismatic astrolabe.

46. **Narrative of the work in Andamans.**—The detachment consisting of Mr. J. B. Mathur, observer, one computer and 12 *khalāsīs* left Dehra Dūn on 15th October 1950 for Madras *en route* to Port Blair, where they reached on 27th October 1950 by *S.S. Maharaja*. The detachment immediately proceeded to the site of the old Chatham Observatory, the position of which had been fixed in 1861 by Mr. Nicholson of the Survey of India. The exact point where observations in 1861, were made could not be identified but a marble slab cemented to the wall of the old observatory indicated the probable position of the old station. A new station was established at this site, which is believed to be within 2 feet of the old one.

Observations with the astrolabe were taken at Chatham on three nights, the work being completed on 3rd November 1950. The detachment then moved to Mount Haughton and observed with the astrolabe on 8th November 1950.

Polaris was also observed for azimuth on the nights of 11th and 12th November with the Geodetic Wild theodolite No. 130. Observations were next taken at Mount Harriet on the nights of 18th and 19th November 1950.

The detachment then returned to Chatham and observed for azimuth by Polaris on the nights of 23rd and 26th November 1950.

Work was closed at Port Blair on 2nd December 1950 and the party returned to Dehra Dūn on 9th December 1950. The equipment of the detachment except the instruments was left at Port Blair for the use of the levelling detachment which

synchronized its arrival in Port Blair with the departure of the deflection detachment.

During the course of the observations, Greenwich time was obtained from Rugby rhythmic time signals emitted at 10·01 and 18·01 G.M.T.

The weather throughout was bad and this considerably hampered the progress of the work. The health of the detachment was satisfactory.

47. Narrative of observations in Rājasthān and Bombay.—After making observations for personal equation and training of Mr. P. P. Chatterji, a research scholar posted by the Government of India for training in Practical Geodesy, the detachment under Mr. J. B. Mathur accompanied by the research scholar, one computer and 12 *khalāsīs* left Dehra Dūn for Nāthdwāra railway station in Rājasthān on 21st January 1951. Work was commenced at Tiki on 28th January, where in addition to the astrolabe observations, azimuth by Polaris was also observed on two nights. The detachment then moved to Tana H.S. where one night's observations with the astrolabe and two night's observations for azimuth were carried out, thus making Tiki H.S. and Tana H.S. a pair of Laplace stations. The observations at Tana H.S. were delayed by 3 days due to haze and clouds. Azimuth observations at both of these stations were made with the Geodetic Wild Theodolite No. 59.

Thereafter, the computer was returned to Dehra Dūn, because Mr. Chatterji had become trained in the routine of observation and recording, and the services of the computer were no longer necessary. The detachment proceeded to the south and took one night's observations at each of the stations Anjini H.S., Tukwāsa H.S., Sagwāra H.S., Kua H.S., Tembla H.S., Jathrabhor H.S., Kāgarol H.S., Richhia H.S. and Pāvāgad H.S. These stations belong to the Singi Meridional series and except in three cases it was always possible to occupy the exact site of the station for observation so that no separate observations for fixing the geodetic position of the observation station were necessary. At Anjini H.S., Tukwāsa H.S. and Pāvāgad H.S. it was found uneconomical to carry the kit of the detachment for encamping close to the site of the G.T. stations. The observations with the astrolabe were made at a temporary station which was connected to the G.T. station by measuring a short base with a steel tape combined with an observed astronomical azimuth.

The detachment closed work at Pāvāgarh in Pānch Mahāls district of Bombay state and returned to Dehra Dūn on 8th March 1951.

48. Personal Equation.—Observations for determining the personal equation were made at Dehra Dūn before proceeding to the Andamans and on return from Port Blair, and again before undertaking the work in Rājasthān and Bombay and on return to Dehra Dūn on the conclusion of the work there. The results

corrected for "demidefinitives" obatined from Bulletin Horaire are as follows :—

Andamans Work

Before Field		After Field	
Date	Personal equation	Date	Personal equation
	s		s
5th October 1950 ..	0·28	19th December 1950	0·21
7th October 1950 ..	0·16		
10th October 1950 ..	0·18		
Mean ..	0·21		
	0·21		

Rājasthān and Bombay Work

Before Field		After Field	
Date	Personal equation	Date	Personal equation
			s
17th January 1951	0·31	14th March 1951	0·34
		16th March 1951	0·32
		Mean ..	0·33
		+0·32	

49. **Astronomical datum for the geodetic triangulation of the Andamans.**—As already mentioned in Chapter I, para 13 the object of the astronomical observations at Chatham Observatory was to establish a datum for the new geodetic triangulation of the Andamans carried out by Mr. U. D. Mamgain during the period under report. The values adopted for the earlier datum point of 1861 fixed by Mr. Nicholson were, latitude 11° 41′ 13″ N., and longitude 92° 42′ 46″ E. The value of latitude, which was fixed from 162 meridional zenith distances, was of a high degree of accuracy and has remained unaltered by the recent reobservations with a 60-degree astrolabe by Mr. J. B. Mathur. The value of longitude was determined from 41 lunar culminations. In 1899, a connection to an intersected point on the coast of Burma, revealed that it was in error by 1′ 16″. This connection was, however, weak (see Technical Report 1948–49, Part III, Chapter I, para 5 and also Chapter I of this report, para 13). The longitude has, therefore, remained always in doubt and the recent redetermination is of great significance. The value now derived lies

midway between the 1861 and 1899 values. The details of the new values of latitude and longitude are as follows :—

Chatham Observatory S.

Date	31-10-50	1-11-50	2-11-50
Number of Prime Vertical stars observed	13	18	14
Number of other stars observed	16	20	16
Latitude	11° 41′ 12″·75	11° 41′ 13″·48	11° 41′ 12″·89
Probable error of latitude ..	± 0″·39	± 0″·65	± 0″·42
Longitude	92° 43′ 29″·82	92° 43′ 30″·00	92° 43′ 30″·67
Probable error of longitude ..	± 0″·41	± 0″·23	± 0″·35

The mean value, i.e., $\lambda = 11° \; 41' \; 13'' \cdot 04$ and $L = 92° \; 43' \; 30'' \cdot 16$ has been accepted.

The azimuth at Chatham Observatory S. of Haughton H.S. is the initial azimuth for the new geodetic series of triangulation.

The details of this azimuth are given below :—

Date	23-11-50	26-11-50
Name of star and number of observations	Polaris (18)	Polaris (19)
Azimuth at Chatham Observatory S. of Haughton H.S.	328° 47′ 19″·64	328° 47′ 19″·92
Probable error	± 0″·16	± 0″·39

The mean value of the azimuth, i.e., 328° 47′ 19″ ·8 has been accepted.

The details of the reverse azimuth that is the azimuth at Haughton H.S. of Chatham Observatory S. are as follows :—

Date	11-11-50	12-11-50
Name of star and number of observations	Polaris (16)	Polaris (14)
Azimuth at Haughton H.S. of Harriet H.S.	170° 00′ 58″·2	170° 00′ 57″·2
Probable error	± 0″·41	± 0″·67

Mean azimuth at Haughton H.S. of Harriet H.S.	170° 00′ 57″ ·7
Angle at Haughton between Harriet H.S. and Chatham Observatory S.	21 13 20 ·3
Azimuth at Haughton H.S. of Chatham Observatory S.	**148 47 37 ·4**

The value 148° 47′ 37″ ·4 given above is in satisfactory agreement with the corresponding value derived by triangulation which is 148° 47′ 37″ ·2.

50. Deviation of the Vertical in the Andamans.—Both components of the deviation of the vertical have been obtained by one night's observations with a large astrolabe at two stations in the Andamans, viz., Haughton H.S. and Mount Harriet H.S. These two stations have been made into Laplace stations as well. The results are tabulated below :—

Name of station	Haughton H.S.	Mount Harriet H.S.
Date	8-11-50	19-11-50
Number of P.V. stars	16	14
Number of others stars	20	16
Astronomical latitude = λ_a ..	11° 38′ 54″·85	11° 43′ 16″·11
Probable error of λ_a	± 0″·65	± 0″·46
Astronomical longitude = L_a ..	92° 44′ 58″·29	92° 44′ 08″·43
Probable error of L_a	± 0″·53	± 0″·18
Geodetic latitude = λ_g	11° 38′ 53″·03	11° 43′ 16″·47
Geodetic longitude = L_g	92° 44′ 56″·21	92° 44′ 09″·15
η = Deflection in the meridian = $\lambda_a - \lambda_g$	+ 1″·82	− 0″·36
ξ = Deflection in P.V. = $(L_a - L_g)\cos\lambda$	+ 2″·04	− 0″·70

Details of Laplace Observations

Station		Astronomical Azimuth at A of B with probable error	Correction* to reduce astronomical azimuth to geodetic	Geodetic azimuth	Azimuth derived by triangulation
			″	° ′ ″	° ′ ″
Haughton H.S.	Harriet H.S.	170 00 57·8 p.e. = ±0·4	−0·4	170 00 57·4	170 00 58·1
Harriet H.S.	Haughton H.S.	350 00 47·7 p.e. = ±0·2	+0·1	350 00 47·8	350 00 48·5

* Correction = $-(L_a - L_g)\sin\lambda_g$.

Assuming deflections at the origin, viz., Chatham Observatory S. to be zero, the deflections on the Everest Spheroid at Haughton H.S. and Mount Harriet H.S. are +1″ ·8, −0″ ·4 in meridian and +2″ ·0 and −0″ ·7 in the prime vertical respectively.

These deflections are in general agreement with the local topography.

51. **Geoidal Section from Tiki to Pāvāgad.**—This season's observations of 11 new stations from Tiki to Pāvāgad between latitudes 25° to $22\frac{1}{2}$° and along the meridian of approximately $73\frac{3}{4}$° E. have provided much useful information about the deflections in this area. The results have been incorporated in the charts of the Geoid and Compensated Geoid in India. On Chart XVIII, the +40-foot contour below Jodhpur has a peak elevation of +46 feet at its centre.

The picture of the Geoid is now well defined in this area but more work in the north of Kutch is indicated to define more clearly the northern rim of the +40-foot contour.

52. **Laplace observations in Rājasthān.**—A twin Laplace observation was made at two of the stations of the above geoidal section (see para 51), viz., at Tiki H.S. and Tana H.S. The former is a station of the Karāchi Longitudinal series. The results are given in the following table :—

Ray	Astronomical azimuth at Tiki H.S. of Tana H.S. with probable error	Correction* to reduce astronomical azimuth to geodetic	Geodetic azimuth	Azimuth by triangulation (published)	Correction to published azimuth
	° ′ ″	″	° ′ ″	° ′ ″	″
Tiki H.S. to Tana H.S.	303 46 15·4 ±0·3	−3·5	303 46 11·9	303 46 12·2	−0·3

* Correction = $-\ (L_a - L_g + 3''\cdot16)\ \sin\lambda_g$.

The deduced error in the published azimuth is satisfactorily small and confirms the accuracy of the Karāchi Longitudinal series.

The correction to the published geodetic azimuth at Birona H.S., which in the nearest Laplace station to Tiki H.S. and about 100 miles west of it, is −1″·1.

Chart XVIII

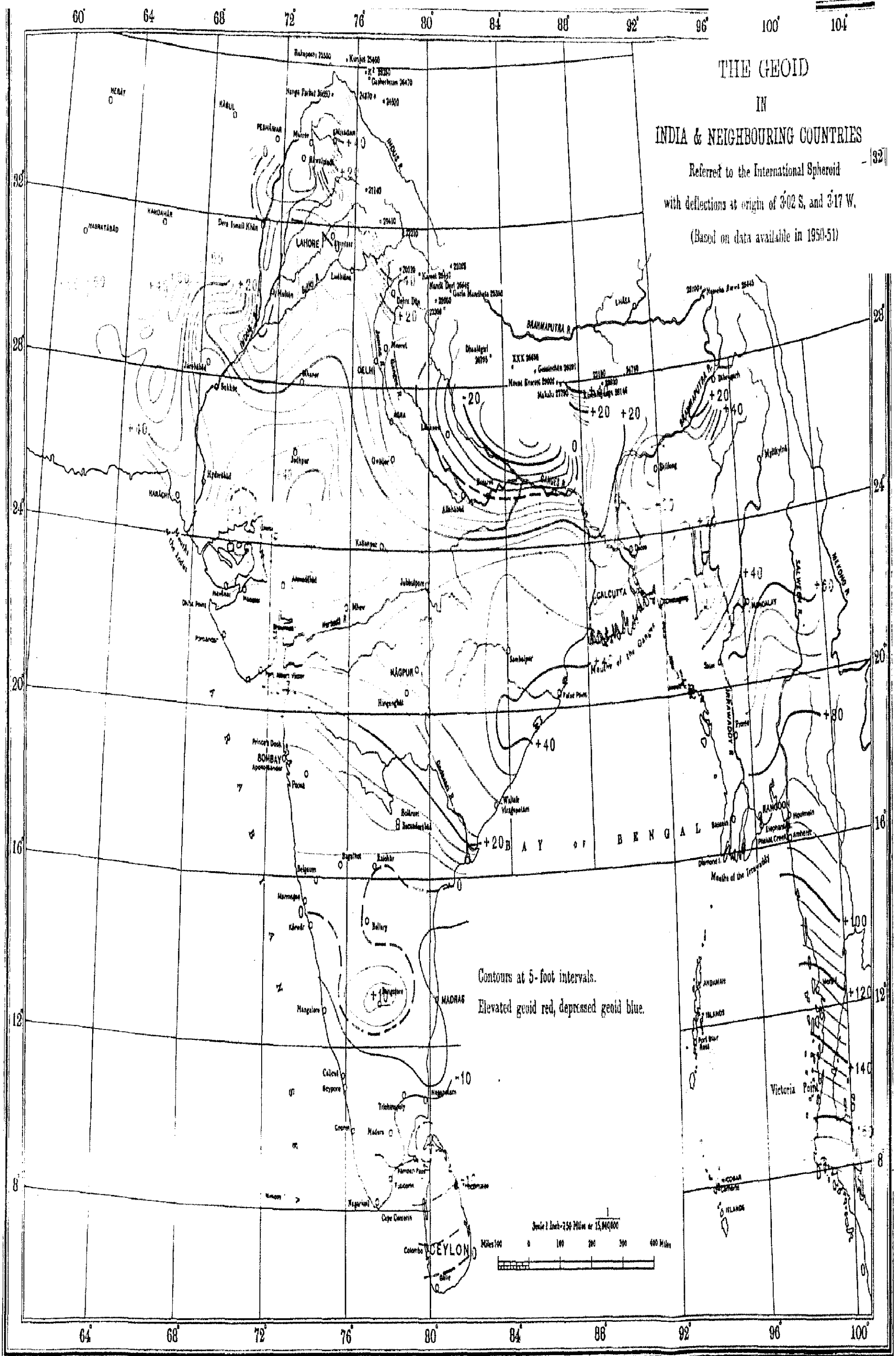

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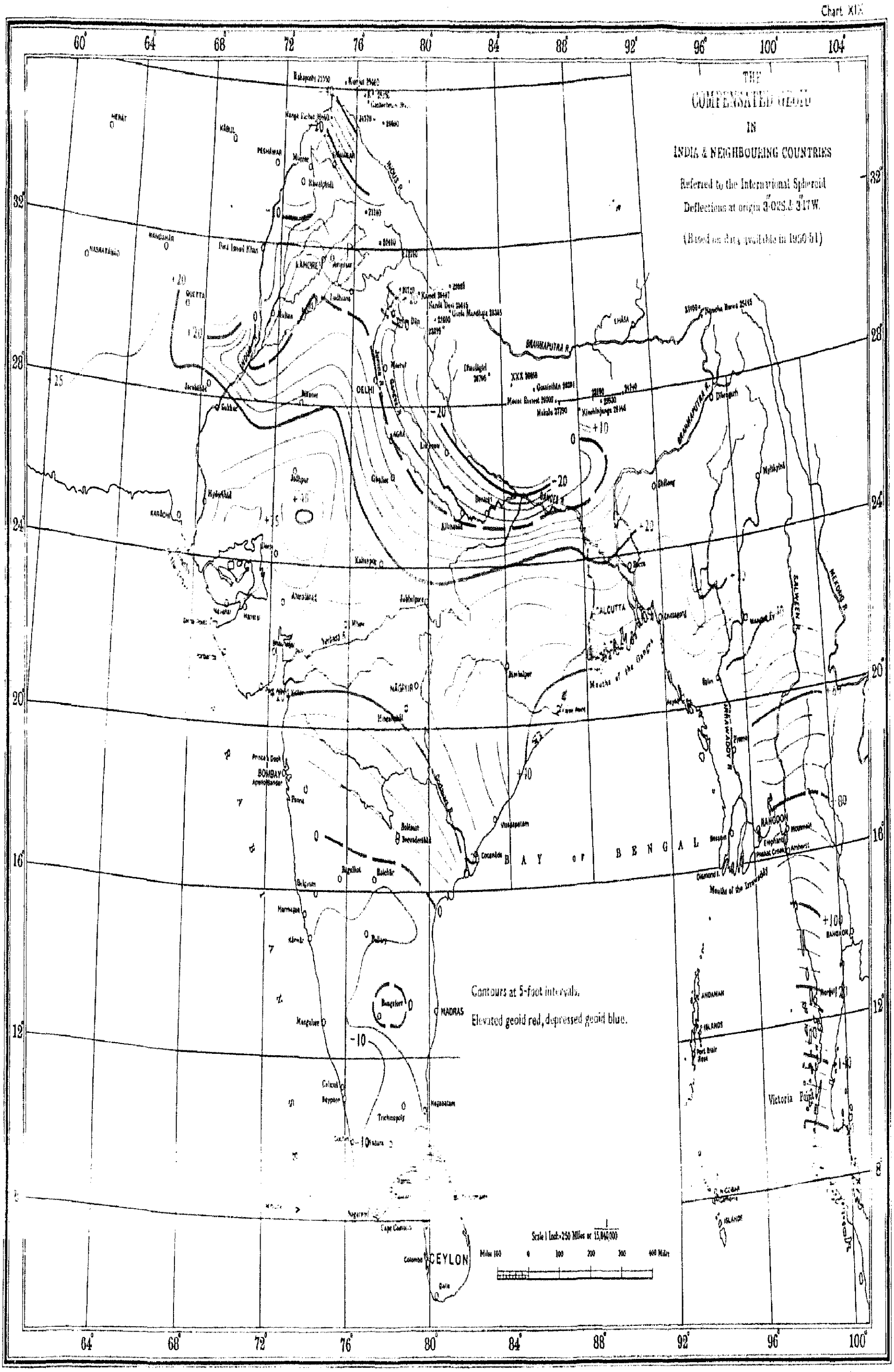
Chart XIX



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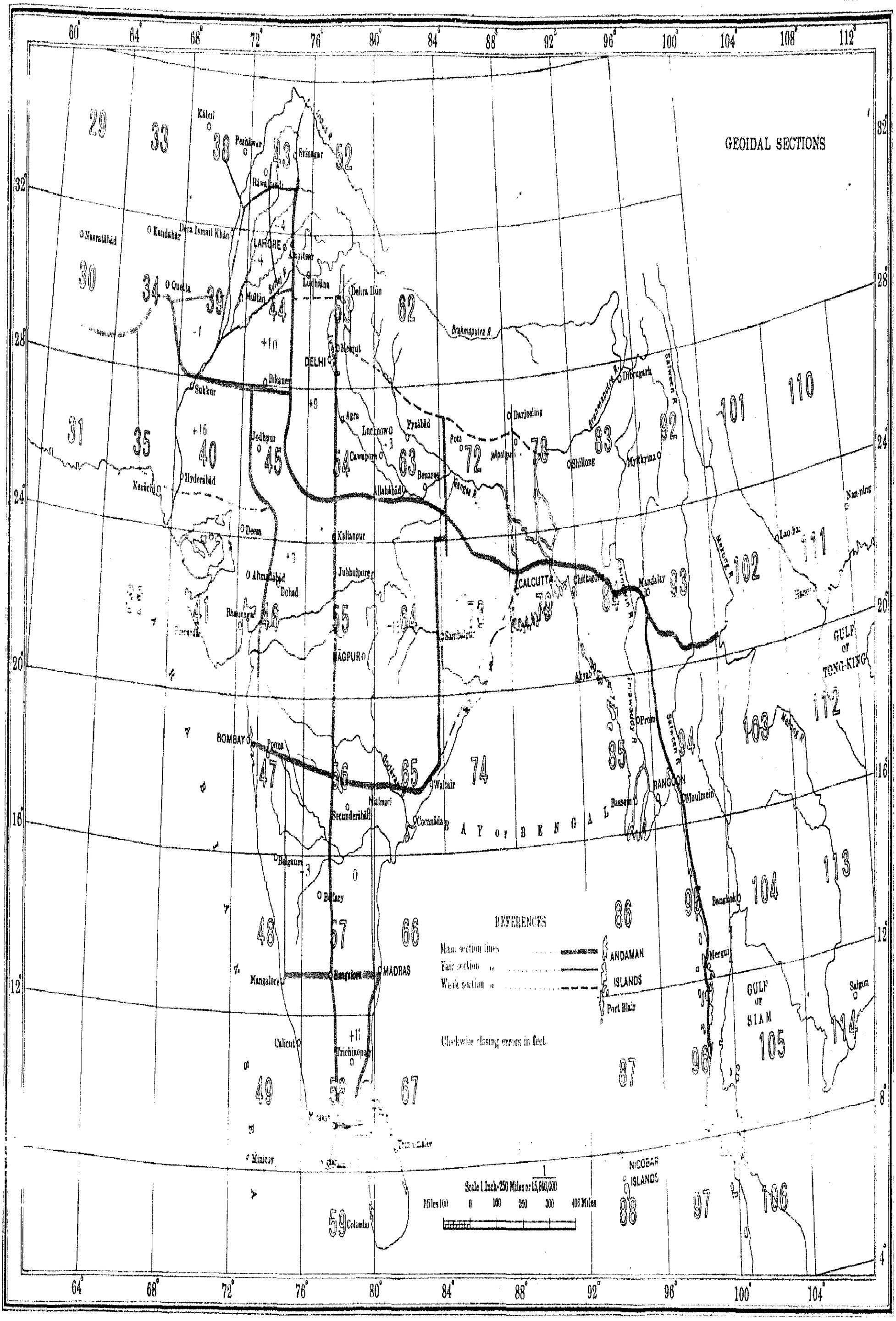

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DEFLECTION STATIONS

TABLE 1

Serial No.	Sheet No.	Observed at	Height in feet	International Spheroid Deflections		Calculated Deflections Hayford System		Calculated Deflections Uncompensated Topography	
				Meridian	P.V.	Meridian	P.V.	Meridian	P.V.
				″	″	″	″	″	″
1211	45 H	Tiki H.S.	2369	− 1·5	+ 5·5				
1212	L	Tana H.S.	2089	− 2·2	+ 6·8				
1213	L	Anjini H.S.	1875	− 5·2	− 0·1				
1214	46 I	Tukwāsa H.S.	1184	− 3·0	+ 1·7				
1215	I	Sagwāra H.S.	976	− 6·1	+ 0·9				
1216	E	Kua H.S.	772	− 5·8	− 0·4				
1217	E	Tembla H.S.	767	− 2·8	− 2·2				
1218	E	Jathrabhor H.S.	798	− 2·9	− 3·1				
1219	F	Kāgarol H.S.	595	− 3·0	− 4·2				
1220	F	Richhia H.S.	542	− 2·1	− 3·4				
1221	F	Pāvāgad H.S.	2721	+ 0·3	− 3·6				

DEFLECTIONS 1950–51

EVEREST'S SPHEROID						Serial No.
Latitude	Longitude	Azimuth	Name of station observed for Azimuth	Deflections		
				Meridian	P.V.	
° ′ ″	° ′ ″	° ′ ″		″	″	
A 24 55 33·65 G 24 55 38·24	A 73 50 49·50 G 73 50 44·41	A 303 46 15·7 G 303 46 12·2	Tāna H.S.	− 4·6	+ 7·5	1211
A 24 42 58·69 G 24 43 03·93	A 74 11 23·55 G 74 11 17·12	A 123 54 53·2 G 123 54 49·7	Tiki H.S.	− 5·2	+ 8·7	1212
A 24 14 22·19 G 24 14 30·13	A 74 08 09·53 G 74 08 10·56			− 7·9	+ 1·9	1213
A 23 56 09·05 G 23 56 14·66	A 74 03 13·60 G 74 03 12·75			− 5·6	+ 3·7	1214
A 23 41 17·21 G 23 41 25·80	A 74 00 01·65 G 74 00 01·68			− 8·6	+ 2·9	1215
A 23 29 13·64 G 23 29 21·90	A 73 54 22·32 G 73 54 23·76			− 8·3	+ 1·6	1216
A 23 15 03·76 G 23 15 08·95	A 73 52 44·40 G 73 52 47·75			− 5·2	− 0·2	1217
A 23 01 44·29 G 23 01 49·45	A 73 40 09·90 G 73 40 14·14			− 5·2	− 1·0	1218
A 22 53 16·93 G 22 53 22·13	A 73 38 59·90 G 73 39 05·19			− 5·2	− 2·0	1219
A 22 41 59·64 G 22 42 03·84	A 73 36 53·06 G 73 36 57·56			− 4·2	− 1·2	1220
A 22 27 42·65 G 22 27 44·33	A 73 30 56·53 G 73 31 01·07			− 1·7	− 1·3	1221

CHAPTER VI

GRAVITY

BY B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

53. **General.**—During the period under report a gravimeter traverse was run with the Frost gravimeter from Lucknow to Delhi via Cawnpore and Agra to compare against the observations taken by Dr. G. P. Woollard in 1948 with his Worden gravimeter (see Technical Report 1948–49, Part III, page 48).

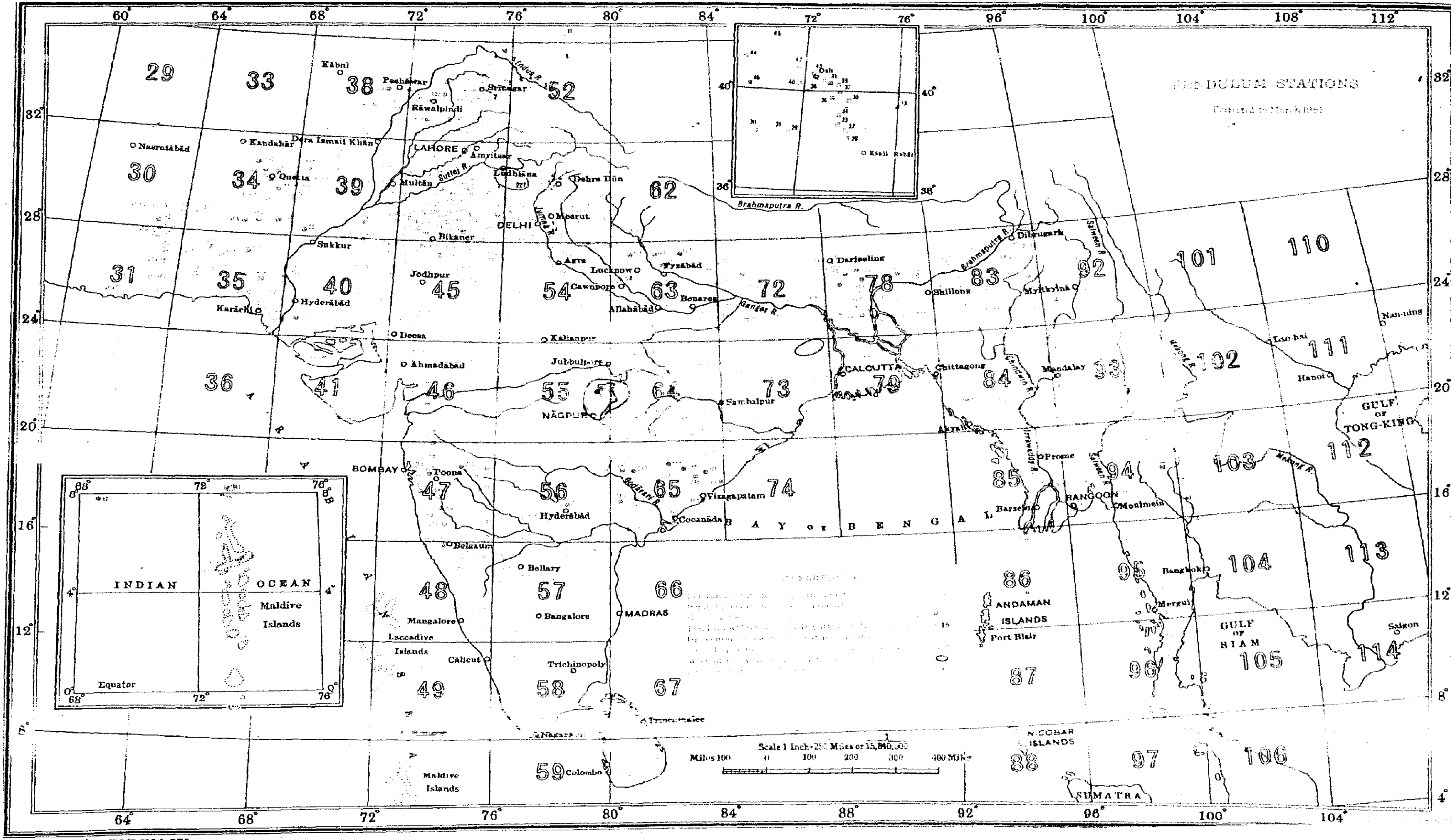
Observations with the Worden gravimeter were also made in collaboration with Mr. Charles Muckenfuss of the University of Wisconsin at several stations in India during his global tour of gravity observations in 1950.

Gravity observations were also carried out at 47 stations in sheets 44 N and 53 B in the Punjab (India) and P.E.P.S.U. Two old pendulum stations were occupied in this area.

54. **Narrative.**—A gravity detachment under Mr. S. Vaikuntanathan, M.A. (Officer Surveyor) with two *khalāsīs* left Dehra Dūn on the forenoon of 31st March 1950 by Jeep for Lucknow. After completing the line Lucknow–Cawnpore–Agra–Delhi, the detachment returned to Dehra Dūn on 20th April 1950. Observations were made at 26 stations.

Mr. Charles Muckenfuss of the University of Wisconsin arrived in India on 20th August 1950 in connection with the programme of global network of gravity stations being established under the auspices of Naval Research Office, Washington. He had with him a long range Worden gravimeter. A suitable itinerary covering a large part of India was evolved by the Director, Geodetic and Training Circle, who met Mr. Muckenfuss at Calcutta and accompanied him during his tour in India to show him the sites of observation stations, and to make a few test observations. Forty stations were observed in all. Mr. Muckenfuss left India on 9th September 1950.

For gravity observations in the Punjab (India) and P.E.P.S.U., Mr. S. Vaikuntanathan left Dehra Dūn on 16th December 1950 by Jeep, with a driver and three *khalāsīs* and after making observations at 47 stations, covering a linear distance of about 1,500 miles, returned to Dehra Dūn on 2nd January 1951. The work was started from the Standard Bench-mark at Ambāla, which had already been connected in 1948 in the course of gravity observations from Dehra Dūn to Simla.


PENDULUM STATIONS
BAY OF BENGAL
GULF OF SIAM
GULF OF TONG-KING
INDIAN OCEAN
Maldive Islands
ANDAMAN ISLANDS
NICOBAR ISLANDS
Laccadive Islands
SUMATRA
Brahmaputra R.
Indus R.
Sutlej R.
Jumna R.
Ganges R.
Godavari R.
Chindwin R.
Irrawaddy R.
Salween R.
Mekong R.
Kābul
Peshāwar
Srinagar
Rāwalpindi
Kandahār
Dera Ismail Khān
LAHORE
Amritsar
Ludhiāna
Quetta
Multān
Dehra Dūn
Meerut
DELHI
Bikaner
Sukkur
Agra
Lucknow
Fyzābād
Cawnpore
Benares
Allahābād
Jodhpur
Hyderābād
Karāchi
Deesa
Kalianpur
Jubbulpore
Ahmadābād
NĀGPUR
Sambalpur
CALCUTTA
Darjeeling
Shillong
Dibrugarh
Myitkyinā
Chittagong
Mandalay
Akyab
Prome
RANGOON
Moulmein
Bassein
BOMBAY
Poona
Vizagapatam
Cocanāda
Belgaum
Bellary
Mangalore
Bangalore
MADRAS
Calicut
Trichinopoly
Colombo
Port Blair
Bangkok
Mergui
Saigon
Hanoi
Nan-ning
Equator
Scale 1 Inch = 250 Miles or 15,840,000
Miles 100 0 100 200 300 400 Miles
29 30 31 33 34 35 36 38 39 40 41 45 46 47 48 49 52 54 55 56 57 58 59 62 63 64 65 66 67 72 73 74 78 79 83 84 85 86 87 88 92 93 94 95 96 97 101 102 103 104 105 106 110 111 112 113 114
60° 64° 68° 72° 76° 80° 84° 88° 92° 96° 100° 104° 108° 112°
4° 8° 12° 16° 20° 24° 28° 32°

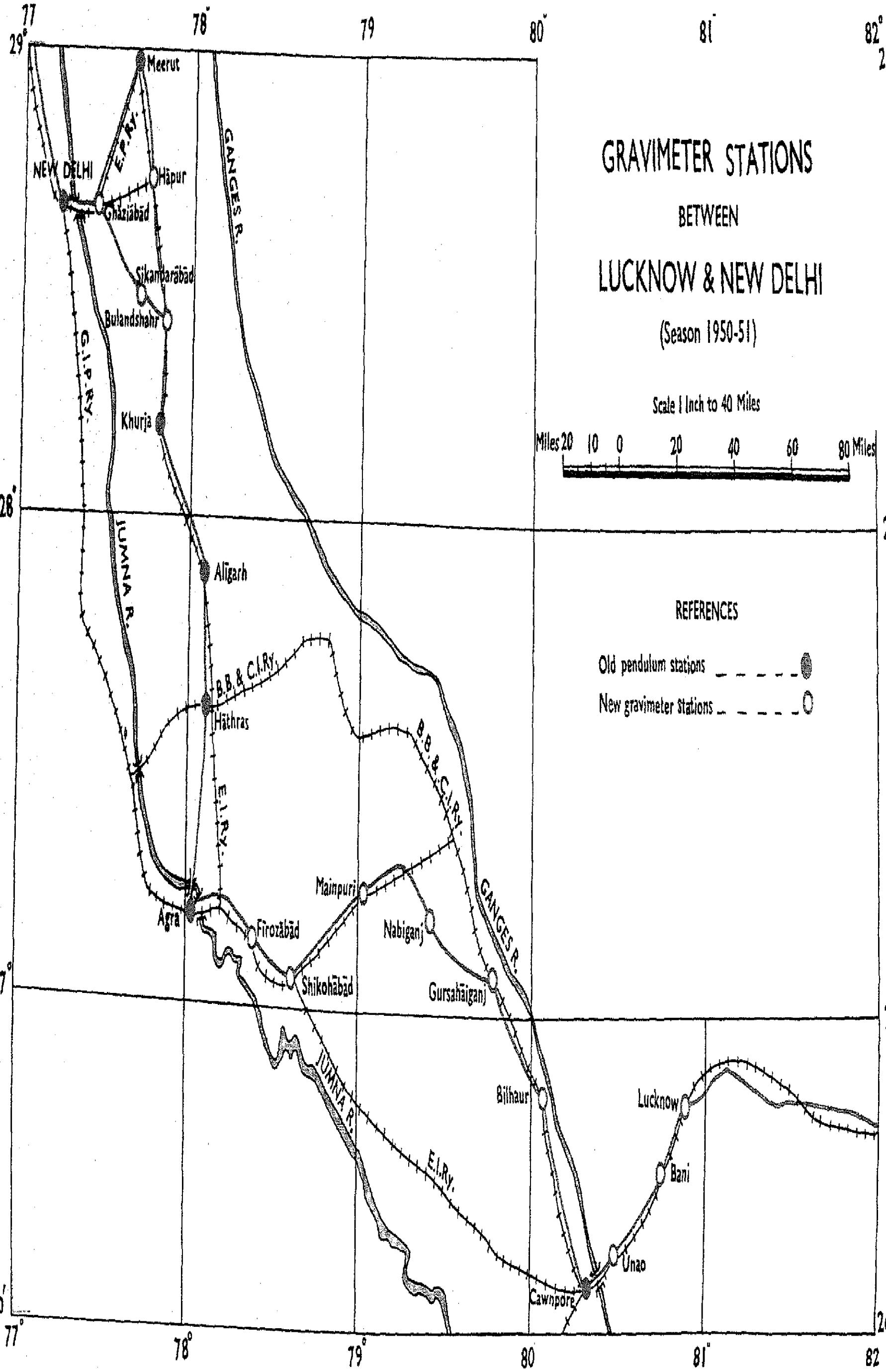


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Chart XXII

55. Results.—(*a*) *Cawnpore to Delhi.*—In the summer of 1949 Dr. Woollard had observed at Cawnpore (Chakeri Air port) and it was considered of interest to connect this station with Delhi by the Frost gravimeter. Work was started from Lucknow and the distance of 400 miles was covered by stages in the course of a week, resetting being involved at some intermediate stations due to the limited range of the Frost gravimeter. The route followed is shown in Chart XXII, stations being established 25 to 30 miles apart. Spirit-levelled heights were available for only a few of the stations. For the remaining, the heights have been read from 1-inch maps and are approximate. The results of these observations are given in Table 1.

Five older pendulum stations lying on the route were also connected. The old and new values of gravity at these stations are shown in Table 6.

The Frost gravimeter behaved very well, the drift being 0·04 milligals per hour on an average.

The gravity difference between Delhi Imperial Hotel pavement and Cawnpore Chakeri Air port as found by Dr. Woollard in 1948 is 160·3 mgals, which agrees very satisfactorily with the Frost gravimeter value of 159·9 mgals. Dr. Woollard, however, reported later that he had to change his value to 161·9 mgals as he had discovered that the pitch of the screw on the primary dial of his gravimeter was not quite uniform. This adjusted value differs from the Frost value by 2 mgals in a range of 160 mgals. This difference is mainly due to the uncertainty in the calibration constant of the Worden gravimeter. Later work in other areas has revealed that Dr. Woollard's adjusted values are burdened with systematic errors up to a maximum of 2 mgals.

TABLE 1.—*Gravimeter stations between Lucknow and Delhi via Cawnpore, 1950.*

Note:—Meter factor used is 0·0817 mgals per dial division.

Serial No.	Sheet No.	Description	Height	Latitude	Longitude	Gravity difference from Lucknow R.S.	Remarks
				(from 1-inch maps)			
			feet			*mgals*	
	63 B	Lucknow Rly. Stn.	385	26 49·9	80 55·1	..	
		„ S.B.M. ..	390*	49·0	56·0	+ 0·1	
		„ Royal Hotel Room No. 34	390	51·0	55·0	+ 1·4	
		Bani P.W.D. I.H.	385	39·0	47·8	1·6	
		Unao P.W.D. I.H.	410	32·8	29·7	1·4	
		Cawnpore Rly. Stn.	405	27·2	21·3	3·5	
		„ S.B.M. ..	404*	28·6	20·6	1·9	
		Chakeri air field..	405*	26 24·1	80 25·0	− 1·	Identical with Dr. Woollard's station (1948).

* Spirit-levelled heights. Other heights are approximate.

contd.)

TABLE 1.—*Gravimeter stations between Lucknow and Delhi via Cawnpore, 1950.*—(concld.)

Note:—Meter factor used is 0·0817 mgals per dial division.

Serial No.	Sheet No.	Description	Height	Latitude (from 1-inch maps)	Longitude (from 1-inch maps)	Gravity difference from Lucknow R.S.	Remarks
			feet	° ′	° ′	mgals	
9	63 B	Cawnpore Circuit House	405	26 27·0	80 21·6	+ 0·1	
10	„	„ M.E.S. I.H. ..	405	27·2	21·5	− 1·8	
..	„	„ Pend. Stn.	412*	27·8	15·5	..	Exact location unknown.
11	„	Bilhaur P.W.D. I.H.	465	26 50·6	80 04·4	+ 9·9	
12	54 M	Gurshaiganj P.W.D. I.H.	480	27 07·0	79 44·0	+ 33·0	
13	„	Mainpuri P.W.D. I.H.	520	15·0	03·0	+ 43·1	
14	„	Nabiganj P.W.D. I.H.	500	11·0	79 24·0	+ 37·2	
15	54 I	Shikohābād P.W.D. I.H.	530	05·0	78 34·8	+ 33·6	
16	„	Shikohābād Canal I.H.	535	05·1	34·8	+ 34·8	
17	„	Firozābād P.W.D. I.H.	540	08·6	24·2	+ 45·3	
18	„	Agra P.W.D. I.H.	550	09·9	00·8	+ 72·6	
19	„	„ S.B.M. ..	525*	10·8	01·4	+ 74·2	
..	„	„ Pend. Stn. ..	535*	10·3	01·3	+ 74·1	Exact position.
..	„	Hāthras Pend. Stn.	587*	36·9	03·4	+ 92·3	Exact position.
..	„	Alīgarh Pend. Stn.	612*	53·5	04·5	+ 95·5	Exact position.
..	„	„ S.B.M. ..	612*	54·4	04·4	+ 96·6	
21	„	„ P.W.D. I.H.	612	27 54·3	78 04·5	+ 96·0	
..	53 H	Khurja Pend. Stn...	649*	28 14·3	77 51·9	+101·3	Exact position.
22	„	Bhur P.W.D. I.H...	669	24·6	50·0	+116·4	
23	„	Hāpur P.W.D. I.H.	694	44·0	46·7	+162·0	
24	„	Sikandrābād P.W.D. I.H.	672	27·3	42·1	+130·4	
25	„	Ghaziābād P.W.D. I.H.	691*	28 40·2	25·1	+155·6	
26		Meerut S.B.M. ..	737*	29 00·0	42·5	+171·3	
..	„	New Delhi Imperial Hotel porch ..	695*	28 37·5	77 13·1	+158·1	Identical with Dr. Woollard's station (1948).

* Spirit-levelled heights. Other heights are approximate

(*b*) *Observations with the Worden Gravimeter.*—In the summer of 1950, Dr. Woollard wrote that he was sending out Mr. Charles Muckenfuss for observations in the South Pacific to improve his world girdling measurements of the previous year. He suggested that it would be possible for him to make a side trip to India for the purpose of direct occupation of Dehra Dūn and checking of some stations. To make the most of the opportunity an itinerary was evolved to solve the following four problems :—

(i) To finalize the value of gravity at our base station Dehra Dūn, and confirm its connection to Pālam air field.

(ii) To have reliable gravity values at the extreme ends of India to serve as sub-standards for work with the Frost gravimeter which has a limited range.

(iii) To check the Frost gravimeter values at some of the mountainous stations such as Mussoorie, Chakrāta, etc., this being necessary on account of some doubt in the pressure compensation of this instrument, and

(iv) To check the pendulum values in Kashmīr area. The Frost gravimeter cannot be carried in an aeroplane and the road communications were too difficult at that time due to the political situation.

The Director, Geodetic and Training Circle accompanied Mr. Muckenfuss to ensure the establishment of stations where they would be most useful.

(i) *Value of gravity at Dehra Dūn.*—An account of the various attempts at determination of the absolute value of gravity from comparison with European stations is given in Chapter III, Technical Report 1948–49, Part III. The last named value of 979·063 gals by Woollard and Gulatee (1948) was derived from a combination of observations with the Worden and Frost gravimeters. Worden gravimeter was used for a carry over from Washington to Delhi and Frost was used from Delhi to Dehra Dūn. At Delhi there was a good agreement between the two instruments at all stations except at Pālam air port where there was a large discrepancy of 10 mgals. (Technical Report 1950, Part III, page 63). In 1950, a direct occupation of Delhi and Dehra Dūn was effected with the

Worden gravimeter, two stations being established *en route.* The results are tabulated below.—

TABLE 2.—*Gravity stations between Dehra Dūn and Delhi*

Serial No.	Description of station	Height	Latitude	Longitude	Frost ‡	Value of *g* Worden (1948)	Value of *g* Worden (1950)
		feet	° ′	° ′	*cm/sec*²	*cm/sec*²	*cm/sec*²
1	Dehra Dūn, National Gravity Station ..	2239	30 19·5	78 03·4	*	*	979·0633
2	Dehra Dūn, Haig Observatory S.B.M. (No. 9/53 J) ..	2233	19·5	03·4	979·0632	(not observed)	979·0631
3	Dehra Dūn, Mr. Gulatee's residence ..	2195†	19·0	03·5	(not observed)	,,	·0647
4	Dehra Dūn, Hāthibarkala survey R.H. ..	2400†	21·0	78 03·6	,,		·0535
5	Fatehpur Dāk-Bungalow ..	985	30 02·8	77 45·8	979·1346	,,	·1351
6	Meerut, S.B.M. No. 27/53 H ..	737	29 00·0	42·0	·1503	,,	·1503
7	New Delhi, Willingdon air port	693	28 35·0	12·7	·1366	979·1357	·1374
8	New Delhi, Imperial Hotel porch ..	695	37·5	13·1	·1370	·1371	·1378
9	New Delhi, Pālam road junction..	799	35·5	09·2	·1324	·1327	·1335
10	New Delhi, Pālam air port ..	720	35·0	07·0	·1328	·1431	979·1336
11	Delhi, Surveyor General's office	701	28 41·1	77 13·5	979·1464	979·1466	(not observed)

* Datum. † Heights approximate.
‡ Meter factor used is 0·0817 mgals per dial division.

Woollard's 1948 values are given in column 7. These values are slightly different from the previous ones tabulated on page 63, Technical Report 1950, Part III, as they have been revised by him to allow for the systematic variation in the relation between the primary and secondary dials of his instrument which were brought to light by later experiments. It is apparent that he made a booking error of one scale division at Pālam air port.

The table also establishes beyond doubt that the accepted value of 979·063 *cm/sec*² at Dehra Dūn needs no change. With the

evidence available so far, however, this value can be reckoned as correct only to 1 mgal or so, although the gravimeter determinations are quoted to 0·1 mgal. The reason is, that the gravimeters are primarily geophysical instruments, meant for being used in limited areas. Their performances in giving results correct to 0·1 mgal when transported over long distances are yet to be proved.

The Worden as an instrument is far more compact and handy than the Frost gravimeter but its drift during these global flights over long distances apparently presents great difficulties. It does not appear to have reached the stage when its calibration constant as determined in the laboratory can be regarded as final during the entire course of the work. Even the pendulum stations which are connected in the circuit of observations have to be utilized for the derivation of the calibration constant though they are of much lesser precision. The only remedy is to return to each base after short intervals which becomes quite cumbrous when the programme occupies a major portion of the globe. As it is, the repeat observations of 1950 at Woollard's stations in India have revealed systematic differences amounting to a maximum of 2 mgals. The Naval Research Office, Washington is contemplating yet another repetition of these world girdling loops to improve their precision and much valuable data in this respect should then be available.

(ii) *Gravity observations at Calcutta.*—Table 3 gives the results at stations observed in the vicinity of Calcutta. These would serve for future use to tie on the chain of stations from Dehra Dūn eastwards to Calcutta as the regional gravity programme of the Survey of India progresses. Already they are serving a useful purpose as the Geological Survey of India which is located at Calcutta is using them to check the calibration of their gravimeters.

TABLE 3.—*Gravity stations near Calcutta*

Serial No.	Description	Height	Latitude	Longitude	Value of g	
					Worden 1948	Worden 1950
		feet	° ′	° ′	*cm/sec²*	*cm/sec²*
1	Calcutta, Great Eastern Hotel ..	20	22 34·0	88 21·2	978·8023	978·8059
2	,, S.B.M. ..	19	32·9	21·5	(not observed)	·8045
3	,, Kidderpore New Dock..	16	31·5	19·0	,,	·8049
4	,, World War I Memorial..	21	33·0	20·0	,,	·8054
5	,, Base Line Tower ..	14	36·9	22·9	,,	·8087
6	,, Sodpur Rly. Stn. ..	21	44·1	22·4	,,	·8127
7	,, Dum Dum Air port ..	14	22 38·4	88 26·3	978·8050	978·8091

The gravity difference between Great Eastern Hotel and Dum Dum Air port was 2·7 mgals in 1948, while the repeat observations of 1950 give it as 3·2 mgals.

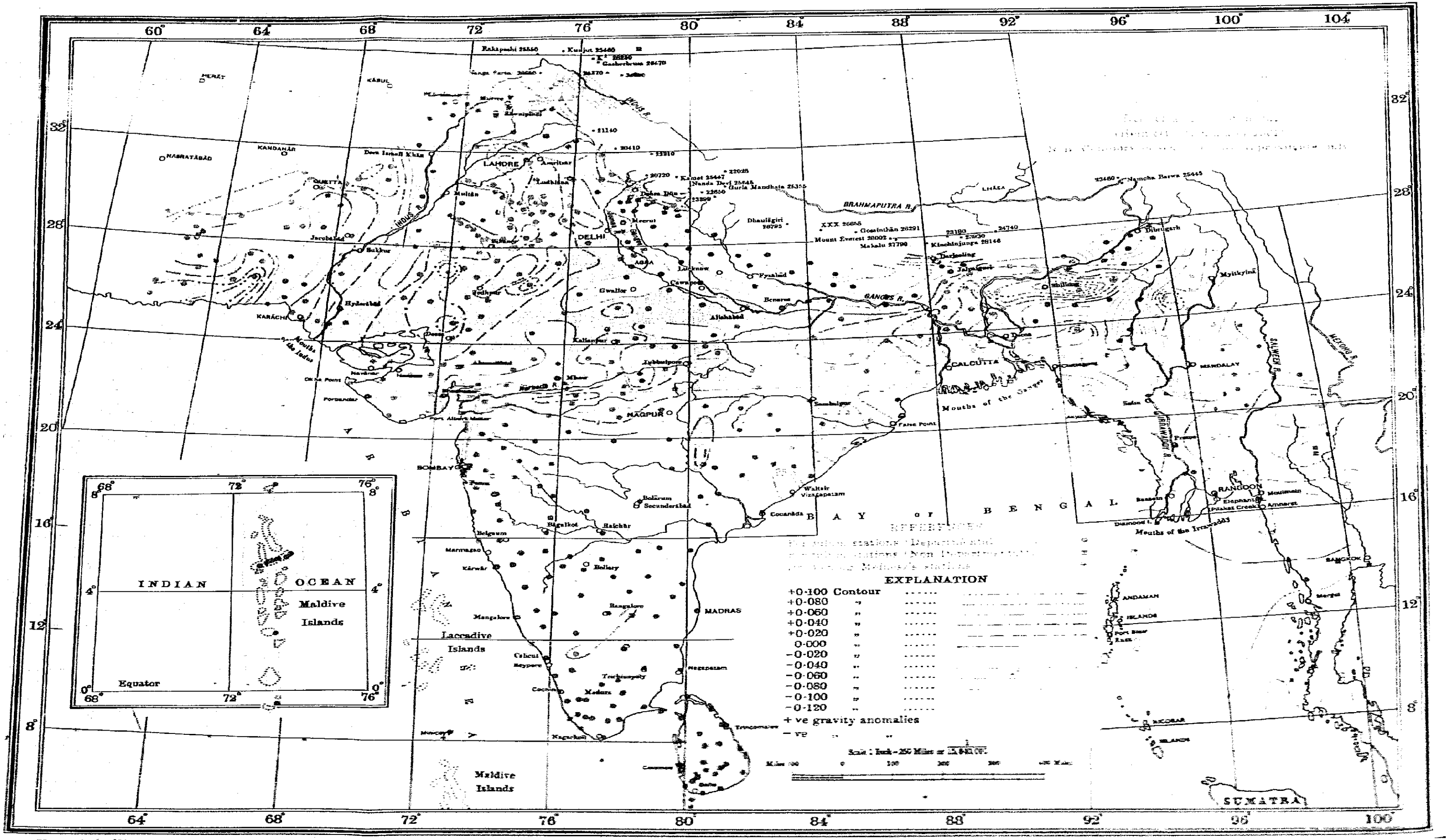
(iii) *Observations at Hill Stations.*—The Frost gravimeter is claimed by the makers to be barometrically compensated for differences of pressure up to 0·7 inch of mercury. It has been noticed to display rather large drifts amounting to as much as 1 mgal per hour when taken through a vertical height of about 1,500 feet in a short time. Opportunity was taken to check the values obtained with it at some hill stations against the Worden gravimeter. Results are given below :—

TABLE 4.—*Gravity observations at Hill Stations*

Serial No.	Description	Height	Latitude	Longitude	Value of g	
					Frost*	Worden 1950
		feet	° ′	° ′	*cm/sec²*	*cm/sec²*
1	Rājpur B.M. No. 169/53 J ..	3334	30 24·0	78 05·1	979·0020	979·0036
2	Bhatta B.M. No. 201 ..	5122	27·2	04·8	978·9054	978·9065
3	Mussoorie B.M. No. 45/53 J ..	6578	27·6	03·9	·8201	·8222
4	Mussoorie Dunseverick pendulum station ..	7129	27·5	03·6	·7763	·7769
5	Mussoorie B.M. No. 48/53 J ..	7123	27·5	78 03·6	978·7771	978·7782
6	Fatehpur I.B. ..	1434	25·9	77 43·6	979·1457	979·1468
7	Kālsi pendulum station	1684	31·1	50·4	·1297	·1309
8	Sahiya bridge B.M. No. 351/53 F ..	3438	36·8	52·6	979·0315	979·0328
9	Chakrāta M.E.S. I.B.	6933	30 42·0	77 52·2	978·8233	978·8247

* Meter factor used is 0·0817 mgals per dial division.

The gravity difference between Rājpur B.M. No. 169/53 J and Chakrāta M.E.S. I.B. is 178·7 mgals by Frost and 178·9 mgals by Worden, which is very satisfactory. But the Mussoorie stations show some erratic differences which exceed the observational errors. The difference between Dunseverick pendulum station and B.M. No. 45/53 J is 43·8 mgals by Frost and 45·3 mgals by Worden. Similarly the difference between Dunseverick pendulum station and B.M. No. 48/53 J which is only a few yards away from it is 0·8 mgal by Frost and 1·3 mgals by Worden. These discrepancies can only be ascribed to errors in the Worden gravimeter as the Frost cannot develop such a large error in so short a distance. A possible explanation may be found in the fact that observations



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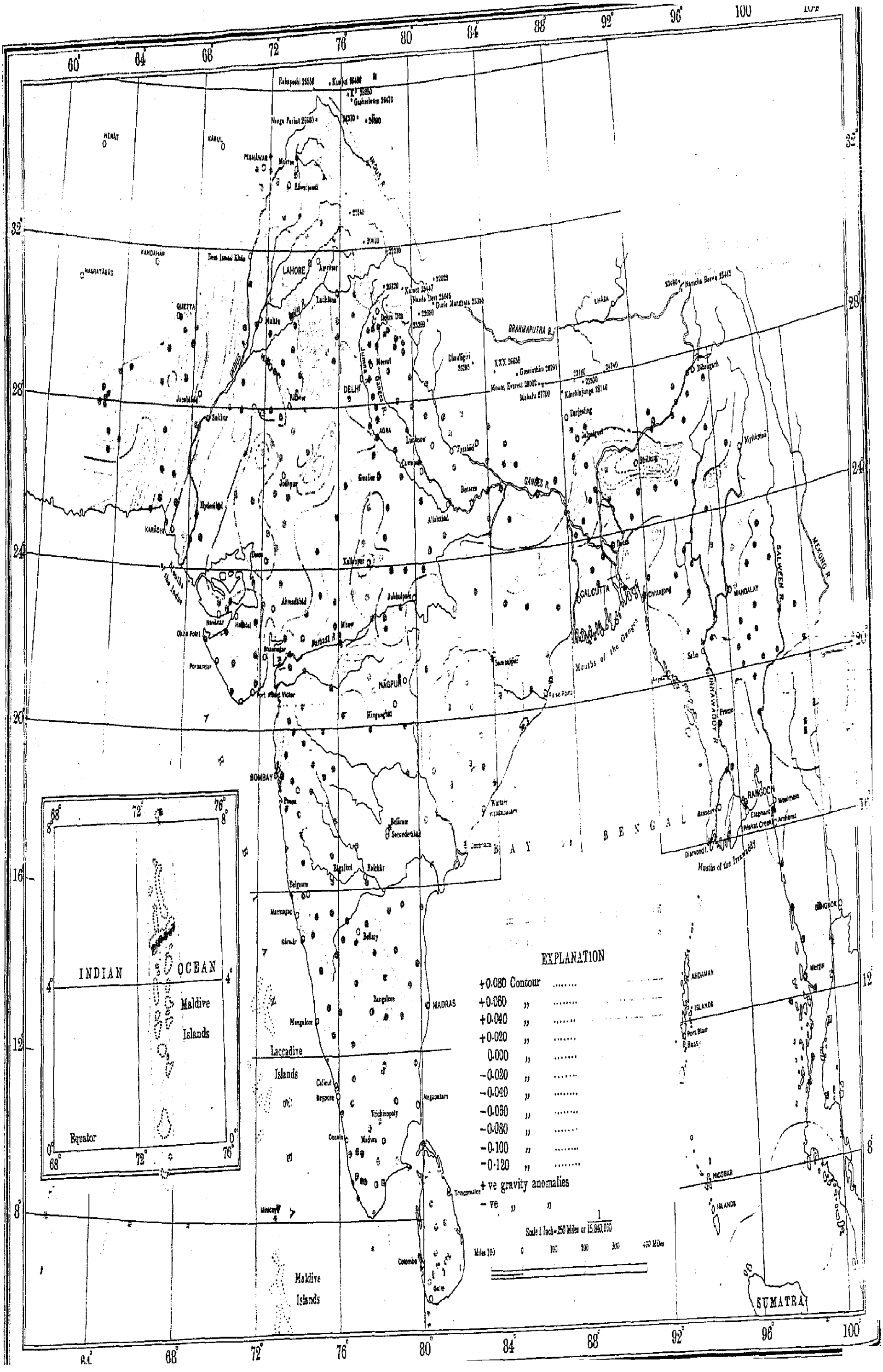

EXPLANATION
+0.080 Contour
+0.060 ,,
+0.040 ,,
+0.020 ,,
0.000 ,,
-0.020 ,,
-0.040 ,,
-0.060 ,,
-0.080 ,,
-0.100 ,,
-0.120 ,,
+ve gravity anomalies
-ve ,, ,,
INDIAN OCEAN
Maldive Islands
Equator
Laccadive Islands
Maldive Islands
BAY OF BENGAL
Mouths of the Ganges
Mouths of the Irrawaddy
SUMATRA
LAHORE
DELHI
KARACHI
CALCUTTA
NAGPUR
BOMBAY
MADRAS
RANGOON
MANDALAY
BRAHMAPUTRA R.
GANGES R.
SALWEEN R.
MEKONG R.
Mount Everest 29002

with the Worden were taken on a very stormy and wet day. More observations at high stations are needed, but it appears that excessive drift exhibited by the Frost gravimeter under these conditions does not necessarily produce results of lower precision.

56. **Observations in Kashmīr.**—In Kashmīr, the pendulum observations were taken in 1925 with brass pendulums manufactured locally at Calcutta. The usual Von Sterneck apparatus of the Survey of India was then away in England for restandardization. These pendulums had rather unsatisfactory knife-edges made of steel. Earlier, Messrs. Alessio and Abetti of De Filippi's Expedition (1914) amongst other things had carried out gravity observations with 8 pendulums between Dehra Dūn and Srīnagar. Their results differed seriously from those of the Survey of India, as would be apparent from the table below :

		De Filippi's Expedition	Survey of India
		cm/sec²	*cm/sec²*
Dehra Dūn	..	979 ·079	979 ·063
Srīnagar ..	..	979 ·090	979 ·095

Not only does the De Filippi's Expedition value disagree with the Survey of India in absolute value at Dehra Dūn, but there is also a serious discrepancy as regards differences of gravity between Srīnagar and Dehra Dūn. As has been seen already, the present work has shown that there is nothing wrong with the accepted value of gravity at Dehra Dūn. From Table No. 5 which gives the results derived with the Worden gravimeter on a flight from Delhi to Srīnagar, it would be seen that the value at Srīnagar pendulum station is 979 ·0819 gals. The Survey of India value was thus in error by 13 mgals here. De Filippi's value was higher by 8 mgals at Srīnagar and 16 mgals at Dehra Dūn. The observers of De Filippi's Expedition Messrs. Alessio and Abetti were very experienced but their pendulums were found on return at Genoa to have undergone considerable changes of length. The results of this expedition can thus be in considerable error.

That De Filippi's values are on the whole too high is confirmed by the observations of Nils Ambolt who was attached to the 1927 expedition of Sven Hedin in Middle Asia. He observed at two stations Yārkand and Leh common to Alessio and found the latter's value higher by 11 and 7 mgals respectively. It appears Alessio had assumed a figure for the lengths of his pendulum which was burdened with a systematic error.

At Gandarbal which is also a station of the Survey of India the observations with the Worden gravimeter have revealed that the error in the older value is only 4 mgals.

The corresponding gravity anomaly contours in Chart XXIII for this area have been corrected. But the contours in the north-

east corner of Sheet 43 are very problematical as they are based on 1925 observation of the Survey of India and De Filippi's results of 1914 both of which are suspect. At station Shādipur (Lat. 34° 11′ 14″, Long. 74° 41′ 00″), the Isostatic gravity anomaly ($g-\gamma_{CH}$) is $-0 \cdot 030$ *cm/sec*^{2}. It is not at all in keeping with the surrounding stations and there is obviously a large observational error here. The whole of this area which is of great scientific interest needs re-observation and a denser net of gravity stations.

57. **Old Pendulum stations.**—The observation of old pendulum stations with the Frost gravimeter now totals 26, including seven stations observed this year. Results are given in Table 6. Barring the large error of 13 mgals at Srīnagar, the reason for which has been explained in the previous paragraph, the discrepancies at the other stations are on the whole within the limit of the observational error of the pendulums.

58. **Observations in the Punjab and P.E.P.S.U.**—Chart XXV shows the gravimeter stations established in Sheets 44 N and 53 B. There are 47 stations in all. The values of observed gravity and the gravity anomalies on various hypotheses are given in Tables 7 and 8.

It would be seen that both the free-air and Bouguer anomalies are negative and show a progressive increase in the north-easterly direction. The Bouguer anomalies are much greater than the free-air ones in magnitude and are indicative of the area being in isostatic equilibrium. Of the various hypotheses of compensation on the Helmert spheroid, Hayford's local compensation and Airy's compensation for the thickness of the earth's crust of 40 km. give the least anomalies. Station No. 48 (Kālka) is at a much higher elevation than the others and marks the beginning of the high positive isostatic anomaly area which lies to its north-east.

Charts XXVI and XXVII show the Hayford isostatic and Bouguer anomaly contours on Helmert spheroid with contour intervals of 5 mgals. The dotted line on the former chart represents the older generalized zero anomaly contour based on pendulum data. The Hayford anomalies are satisfactorily small. A negative anomaly belt extends from Ambāla to Chamkor in a north-westerly direction, flanked on both sides by positive anomalies. This deficient area marks the tail end of the conspicuous negative anomaly zone in the alluvial plains at the foot of the Himālayas.

Chart XXV

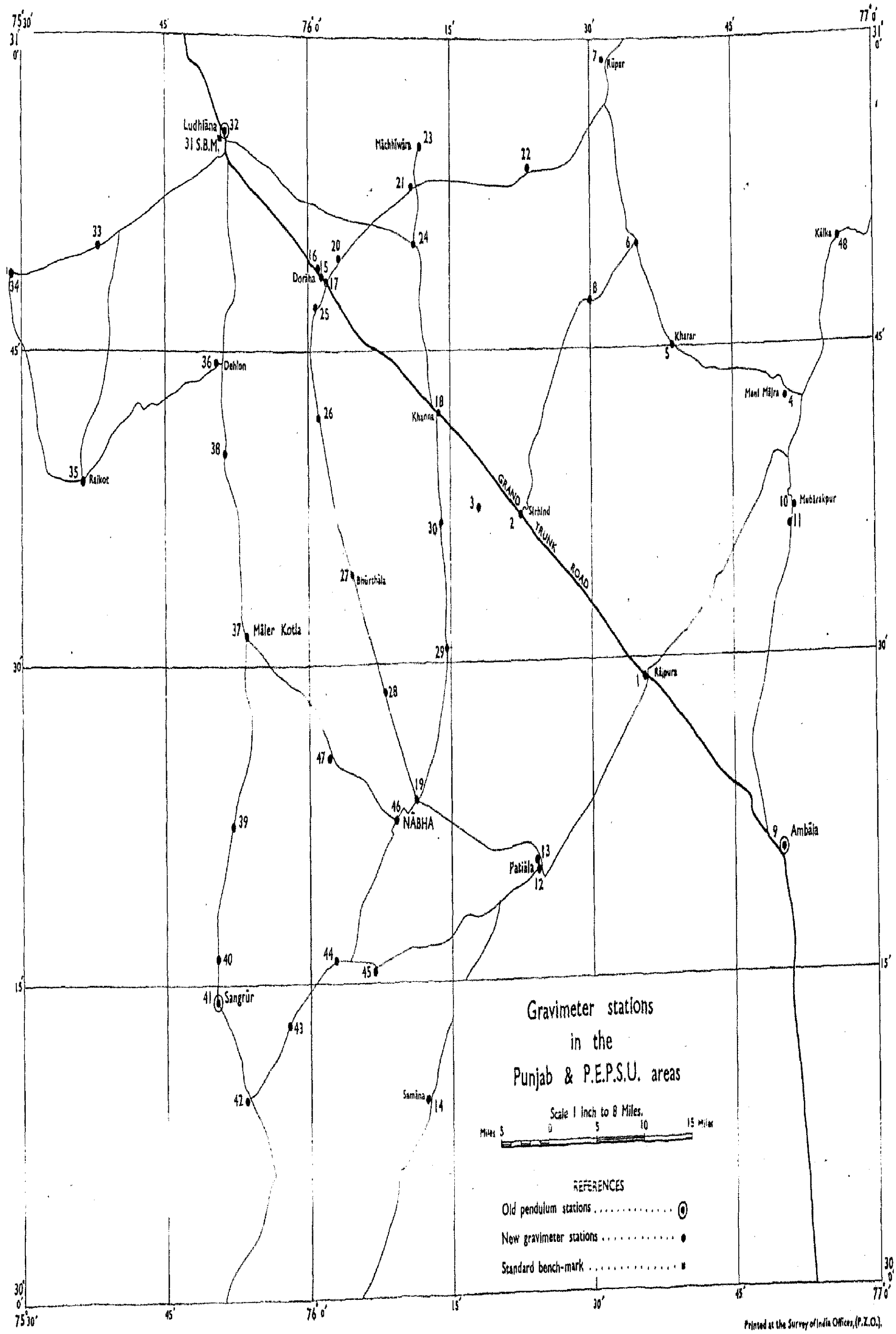

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Chart XXVI

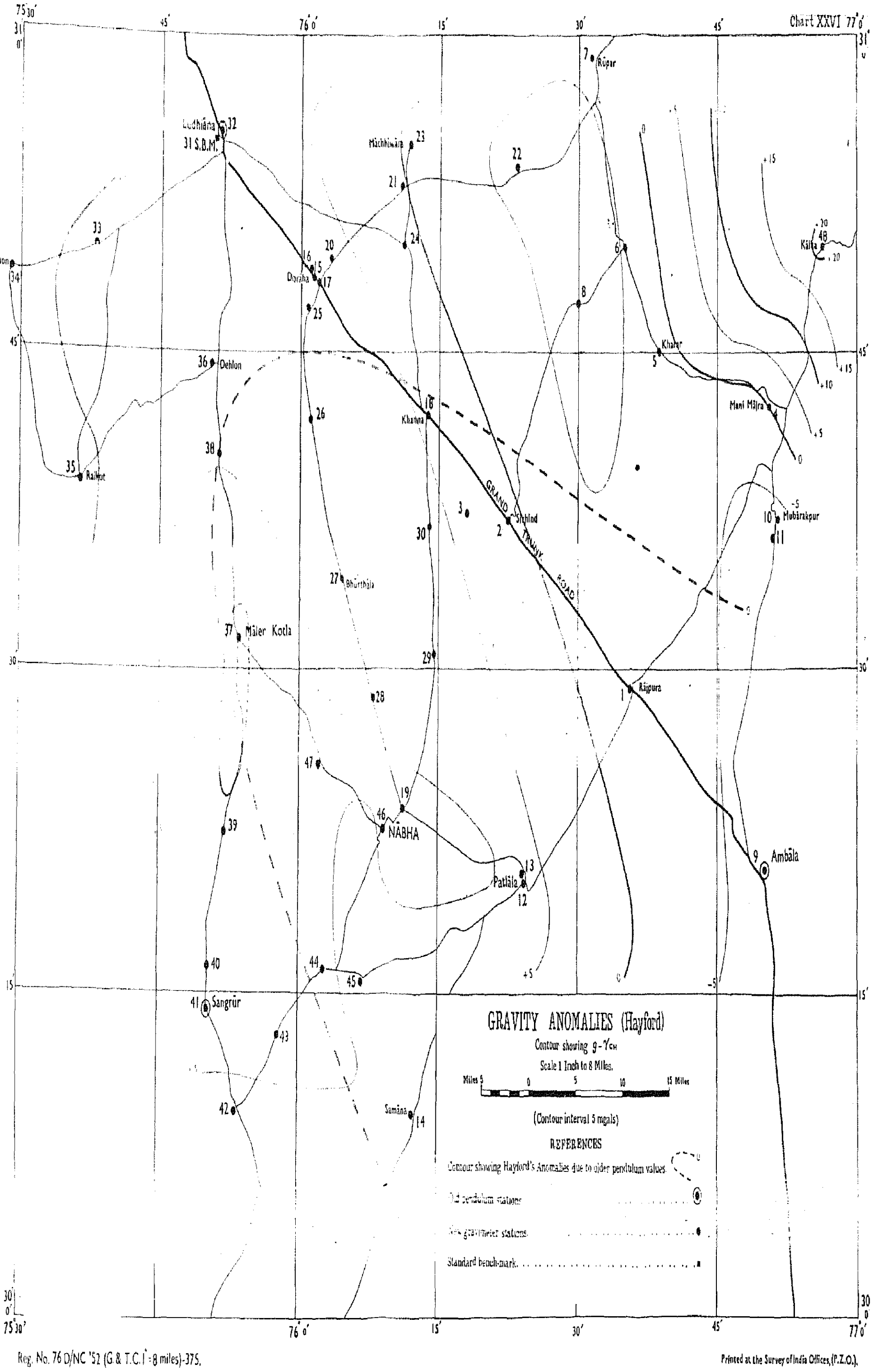

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Chart XXVII

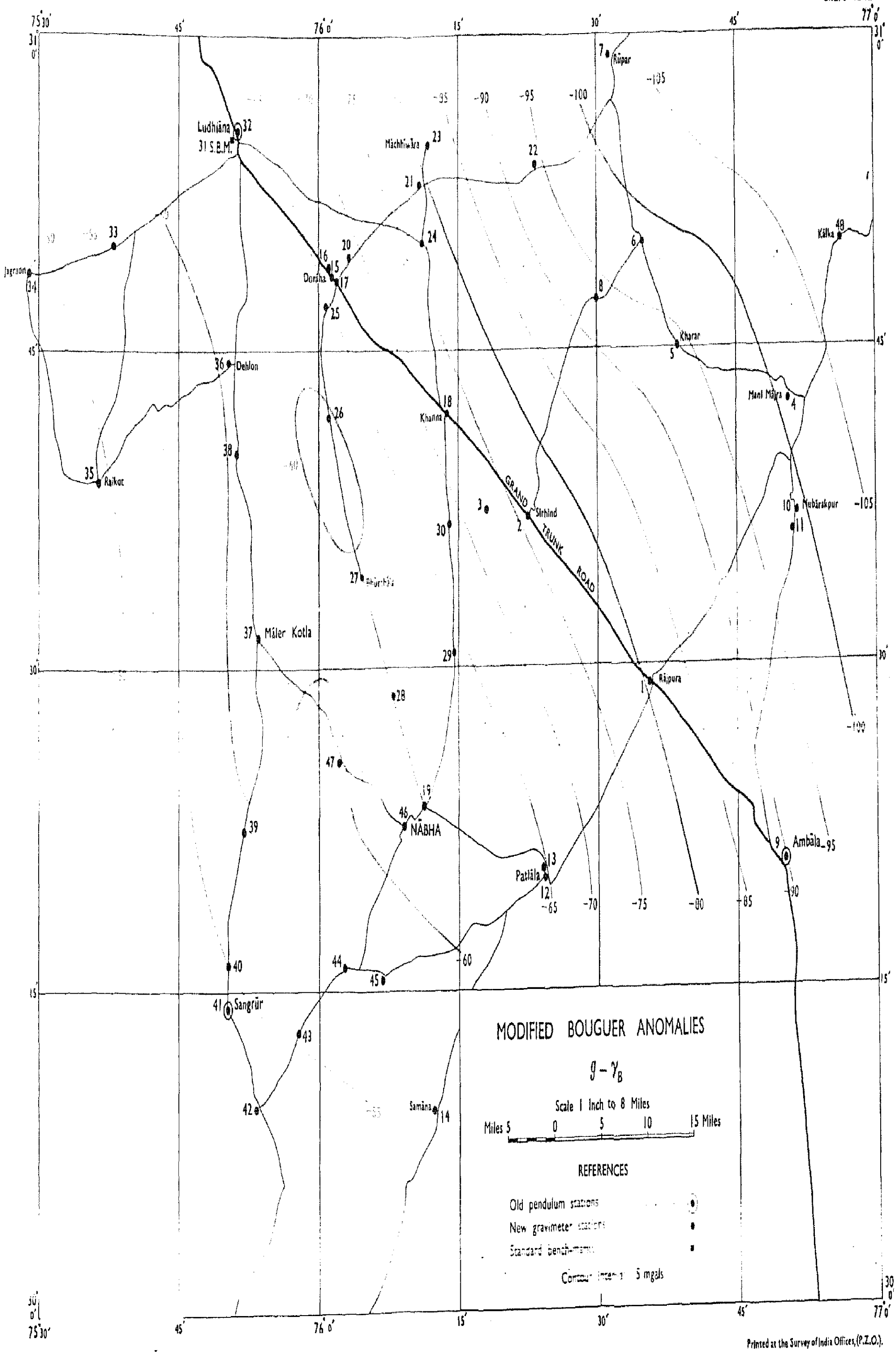

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TABLE 5.—*Gravity stations in Kashmīr area*

erial No.	Description of station	Height	Latitude	ongitude	Value of g Worden 1950
		feet			*cm/sec*^{2}
	Delhi, Pālam air port ..	720*	28 35·0	77 07·0	979·1336
	Amritsar air port.. ..	755*	31 38·3	74 52·0	·3481
	Jammu air port	1020*	32 43·0	52·0	·3481
	Srīnagar air port	5200*	34 07·0	48·0	·0440
	,, pendulum station (Nedou's hotel) ..	5198	04·6	49·4	·0819
	,, B.M. No. 94 ..	5210	04·1	48·5	·0711
	,, club	5210*	04·5	49·5	·0832
	,, H.B. Flora ..	..	..	..	·0777
	,, Mile-post 103 ..	5220*	07·0	49·0	·0763
	,, Pandah B.T.L. 50 ..	5283*	11·0	48·0	·0651
	,, B.M. No. 107 ..	5223	12·3	48·0	·0712
	Gandarbal pendulum station..	5200	34 12·8	74 46·2	979·0781

Approximate. Others are spirit-levelled heights.

TABLE No. 6.—*Gravity values—Pendulum and Frost Gravimeter*

Serial No.	No. of Pendulum station	Sheet No.	Name of Station	Height	Latitude	Longitude	Years of observation	Pendulum value	Gravimeter value*	Pendulum *minus* gravimeter	REMARKS
				feet	° ′ ″	° ′ ″		*gals*	*gals*	*mgals*	
1	1	53 J	Dehra Dūn ..	2239	30 19 29	78 03 22	..	979·063	..	..	Base station.
2	39	„	Rājpur ..	3321	30 24 02	78 05 07	1929, 1947	979·002	979·0030	− 1·0	Probable position.
3	4	„	Dunseverick (Mussoorie) ..	7129	30 27 28	78 03 33	1904, 1948	978·776	978·7763	− 0·3	Exact position.
4	5	„	Camels' Back (Mussoorie) ..	6921	30 27 35	78 04 32	1904, 1948	·793	·7918	+ 1·2	Pendulum station does not exist. Approximate position.
5	184	53 F	Chakrāta ..	6933	30 41 58	77 52 10	1929, 1947	978·819	978·8234	− 4·4	Approximate position.
6	30	53 G	Roorkee ..	867	29 52 20	77 53 59	1906, 1947	979·129	979·1289	+ 0·1	Exact position.
7	31	„	Nojli	879	29 53 28	77 40 25	1906, 1947	·143	·1420	+ 1·0	„ „
8	37	53 F	Fatehpur ..	1434†	30 25 53	77 43 37	1907, 1947	·147	·1457	+ 1·3	„ „
9	38	„	Kālsi	1684	30 31 08	77 50 26	1907, 1947	·131	·1297	+ 1·3	„ „
10	35	„	Mohan ..	1660	30 10 53	77 54 37	1907, 1947	·109	·1086	+ 0·4	„ „
11	29	53 K	Hardwār ..	949	29 56 29	78 09 19	1906, 1947	·122	·1235	− 1·5	„ „
12	227	53 B	Ambāla ..	888	30 20 13	76 50 00	1931, 1948	·200	·2014	− 1·4	Approximate position.
13	17	„	Kālka	2202	30 50 08	76 56 22	1905, 1948	979·147	979·1462	+ 0·8	Exact position.
14	16	53 E	Simla	7043	31 06 19	77 09 50	1905, 1948	978·840	978·8410	− 1·0	„ „
15	33	53 G	Meerut ..	734	29 00 28	77 41 40	1907, 1949	979·151	979·1517	− 0·7	„ „

* Meter factor used is 0·0817 mgals per dial division.

† Approximate. Others are spirit-levelled heights.

(contd.)

TABLE No. 6.—*Gravity values—Pendulum and Frost Gravimeter*—(concld.)

Serial No.	No. of pendulum station	Sheet No.	Name of Station	Height	Latitude	Longitude	Years of observation	Pendulum value	Gravimeter value*	Pendulum *minus* gravimeter	REMARKS
				feet	° ′ ″	° ′ ″		*gals*	*gals*	*mgals*	
16	376	53 H	Delhi	715	28 41 21	77 12 53	1935, 1949	979·146	979·1464	− 0·4	Exact position.
17	18	44 N	Ludhiāna ..	835	30 55 25	75 51 09	1906, 1950	·274	·2768	− 2·8	,, ,,
18	409	,,	Sangrūr ..	772	30 14 37	75 50 06	1936, 1950	·240	·2375	+ 2·5	,, ,,
19	108	53 H	Khurja ..	649	28 14 19	77 51 53	1913, 1950	·082	·0803	+ 1·7	,, ,,
20	104	54 I	Agra	535	27 10 20	78 01 07	1913, 1950	·056	·0532	+ 2·8	,, ,,
21	106	54 I	Hāthras ..	587	27 36 52	78 03 22	1913, 1950	·075	·0713	+ 3·7	,, ,,
22	107	,,	Aligarh ..	612	27 53 32	78 00 31	1913, 1950	979·075	979·0745	+ 0·5	,, ,,
23	262	63 B	Shahpur (Cawnpore) ..	412	26 27 50	80 15 29	1932, 1950	978·973	978·9771	− 4·1	Approximate position about 8 feet lower than the pendulum station.
24	145	43 J	Srinagar ..	5198	34 04 36	74 49 27	1925, 1950	979·095	979·0819†	+13·1	Exact position.
25	136	,,	Gandarbal ..	5200	34 12 48	74 46 09	1925, 1950	979·082	979·0781†	+ 3·9	,, ,,
26	254	79 B	Barrackpore ..	21	22 45 59	88 20 50	1932, 1950	978·810	978·8068†	+ 3·2	Approximate position, about 7 feet lower than the pendulum station.

Meter factor used is 0·0817 mgals per dial division.

† Observations at these stations are with Worden gravimeter.

TABLE 7.—*Gravity Anomalies in East*

No.	Stations	Height	Latitude	Longitude	g (metre factor 0·0817)	HEL		
						$g-\gamma_A$	$g-\gamma_B$	Modified $g-\gamma_B$†
		feet	° ′ ″	° ′ ″	*gals*	*mgals*	*mgals*	*mgals*
1	Rājpura R.H.	882*	30 29 13	76 35 36	979·2218	− 55·1	− 83·2	− 82·2
2	Sirhind P.S.	868*	36 58	22 21	·2393	− 49·1	− 78·3	− 75·8
3	Kumra T.S.	869	37 20	18 03	·2405	− 48·3	− 77·5	− 74·9
4	Mānimājra ..	1136*	42 55	50 33	·2048	− 66·4	−104·6	−103·2
5	Kharar R.H.	1012	45 00	38 33	·2225	− 63·0	− 97·0	− 93·1
6	Kurali Dispensary ..	981	49 48	34 50	·2271	− 67·7	−100·7	− 98·0
7	Rūpar Canal R.H.	891	58 44	31 02	·2382	− 76·8	−106·8	−104·1
8	Mūrinda P.S.	924*	47 31	30 00	·2295	− 67·6	− 98·7	− 95·9
9	Ambāla S.B.M.	900	20 40	50 20	·2023	− 61·7	− 92·0	− 89·3
10	Mubārakpur I.B.	992	37 05	51 18	·2048	− 72·2	−105·5	−102·9
11	Ghaggar R.S.	979	36 38	51 00	·2040	− 73·6	−106·5	−104·2
12	Wheel Guard (Patiāla)	832	20 17	24 25	·2307	− 39·2	− 67·2	− 64·6
13	Patiāla railway station	829	20 22	24 10	·2309	− 39·3	− 67·2	− 64·7
14	Samāna Road Junction	783	09 34	12 41	·2281	− 32·3	− 58·6	− 56·3
15	Dorāha P.W.D.R.H.	844	48 13	01 20	·2654	− 40·1	− 68·5	− 66·0
16	B.M. on Mile 59/12 ..	848	48 38	00 54	·2659	− 39·8	− 68·3	− 65·8
17	Sirhind Canal B.M. ..	857	48 00	01 48	·2644	− 39·6	− 68·4	− 65·7
18	Khanna Petrol pump	867*	42 16	13 28	·2505	− 45·0	− 74·1	− 71·6
19	Rohti I.B.	831	23 36	11 30	·2368	− 37·4	− 65·3	− 62·8
20	Dorāha Canal R.H.	849	49 15	03 18	·2644	− 42·1	− 70·6	− 68·1
21	Garhi Canal R.H.	855	53 09	10 52	·2583	− 52·7	− 81·4	− 79·0
22	Chamkor Canal R.H.	893	54 00	23 42	·2394	− 69·1	− 99·1	− 96·3
23	Māchhiwara P.T.O. ..	865	54 49	12 03	·2558	− 56·5	− 85·6	− 82·9
24	Samrāla D.B.R.H.	860	50 20	11 20	·2564	− 50·3	− 79·2	− 76·6
25	Mānpur Canal R.H.	845	46 51	00 44	·2650	− 38·5	− 66·9	− 64·4
26	Dahmot R.H.	840	41 38	01 14	·2635	− 33·6	− 61·8	− 59·3
27	Bhūrthala R.H.	848	34 06	04 22	·2523	− 34·3	− 62·8	− 60·1
28	Bhūra R.H.	828	28 34	08 10	·2436	− 37·5	− 65·3	− 62·9
29	Bhādson ..	850	30 44	14 32	·2436	− 38·3	− 66·9	− 64·3
30	Amloh Road Junction	846	36 39	13 53	·2464	− 43·6	− 72·0	− 69·6
44	Bhawānīgarh ..	790*	16 00	02 36	·2330	− 35·2	− 61·8	− 59·4
45	Nadimpur ..	797	15 28	06 48	·2350	− 31·8	− 58·6	− 56·2
46	Malerkotla-Nābha Road Junction ..	815*	22 51	08 20	·2390	− 35·7	− 63·1	− 60·7
47	Bāgriān ..	810*	25 38	02 12	·2440	− 34·9	− 62·1	− 59·7
48‡	Kālka (Pend. Stn.) ..	2202	30 50 08	76 56 22	979·1462	− 34·6	−108·6	−108·0
	Mean with regard to sign					− 48·1	− 78·7	− 76·2
	Mean without regard to sign ..					48·1	78·7	76·2
	Range					45·0	50·0	51·8

* Approximate heights.
† Modified $g-\gamma_B = g-\gamma_A$−attraction of topography up to zone O.
‡ Observed in Season 1948–49.

Punjab and P.E.P.S.U. (Sheet 53 B)

MERT'S FORMULA					INTERNATIONAL FORMULA				
Hayford's compen-sation 113·7 km.	HEISKANEN'S REGIONAL COMPENSATION				Hayford's compen-sation 113·7 km.	HEISKANEN'S REGIONAL COMPENSATION			
	40 km.	60 km.	80 km.	100 km.		40 km.	60 km.	80 km.	100 km.
mgals	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*
− 2·1	− 6·9	+ 8·1	+19·6	+28·2	−18·5	−23·3	− 8·3	+ 3·2	+11·8
+ 1·8	− 4·7	+10·8	+22·3	+30·9	−14·6	−21·1	− 5·6	+ 5·9	+14·5
+ 1·5	− 5·0	+10·2	+21·4	+30·1	−14·9	−21·4	− 6·2	+ 5·0	+13·7
+ 0·6	+ 0·9	+14·7	+24·5	+31·8	−15·8	−15·5	− 1·7	+ 8·1	+15·4
− 0·1	− 0·9	+14·8	+25·9	+34·1	−16·5	−17·3	− 1·6	+ 9·5	+17·7
− 4·6	− 5·9	+19·9	+21·7	+29·9	−21·0	−22·3	+ 3·5	+ 5·3	+13·5
− 4·3	− 5·5	+11·2	+23·0	+31·5	−20·7	−21·9	− 5·2	+ 6·6	+15·1
− 8·7	−11·0	+ 4·9	+17·3	+25·7	−25·1	−27·4	−11·5	+ 0·9	+ 9·3
− 6·9	− 9·0	+ 6·2	+17·1	+25·8	−23·3	−25·4	−10·2	+ 0·7	+ 9·4
− 6·4	− 7·4	+ 7·5	+17·9	+26·0	−22·8	−23·8	− 8·9	+ 1·5	+ 9·6
− 8·1	− 9·0	+ 6·0	+16·3	+24·3	−24·5	−25·4	−10·4	− 0·1	+ 7·9
+ 5·3	− 1·0	+12·9	+23·8	+32·4	−11·1	−17·4	− 3·5	+ 7·4	+16·0
+ 5·2	− 1·1	+12·8	+23·7	+32·2	−11·2	−17·5	− 3·6	+ 7·3	+15·8
+ 5·5	− 1·0	+11·1	+21·2	+29·1	−10·9	−17·4	− 5·3	+ 4·8	+12·7
+ 7·6	+ 0·9	+15·6	+27·2	+36·4	− 8·8	−15·5	− 0·8	+10·8	+20·0
+ 8·0	+ 1·1	+15·8	+27·5	+36·8	− 8·4	−15·3	− 0·6	+11·1	+20·4
+ 8·0	+ 1·3	+16·0	+27·6	+37·0	− 8·4	−15·1	− 0·4	+11·2	+20·6
+ 5·0	+ 0·1	+15·7	+27·7	+36·4	−11·4	−16·3	− 0·7	+11·3	+20·0
+ 3·7	− 3·0	+10·6	+20·7	+29·2	−12·7	−19·4	− 5·8	+ 4·3	+12·8
+ 6·1	− 0·5	+14·4	+26·0	+35·3	−10·3	−16·9	− 2·0	+ 9·6	+18·9
+ 1·1	− 3·5	+12·7	+24·5	+33·6	−15·3	−19·9	− 3·7	+ 8·1	+17·2
− 6·1	− 8·2	+ 8·8	+20·4	+29·1	−22·5	−24·6	− 7·6	+ 4·0	+12·7
− 2·2	− 6·9	+ 9·5	+21·4	+30·6	−18·6	−23·3	− 6·9	+ 5·0	+14·2
+ 3·2	− 1·6	+14·4	+26·3	+35·2	−13·2	−18·0	− 2·0	+ 9·9	+18·8
+ 8·7	+ 2·1	+16·8	+28·4	+37·4	− 7·7	−14·3	+ 0·4	+12·0	+21·0
+10·3	+ 4·0	+18·1	+29·2	+38·1	− 6·1	−12·4	+ 1·7	+12·8	+21·7
+ 8·0	+ 1·7	+15·3	+26·2	+34·7	− 8·4	−14·7	− 1·1	+ 9·8	+18·3
+ 4·9	− 1·6	+11·8	+22·5	+31·0	−11·5	−18·0	− 4·6	+ 6·1	+14·6
+ 8·6	+ 2·0	+16·3	+27·2	+35·6	− 7·8	−14·4	− 0·1	+10·8	+19·2
+ 4·5	− 2·0	+12·5	+24·1	+32·7	−11·9	−18·4	− 3·9	+ 7·7	+16·3
+ 1·6	− 4·7	+ 7·4	+17·1	+25·2	−14·8	−21·1	− 9·0	+ 0·7	+ 8·8
+ 5·9	− 0·7	+11·6	+21·6	+29·7	−10·5	−17·1	− 4·8	+ 5·2	+13·3
+ 5·1	− 0·9	+12·5	+22·4	+30·6	−11·3	−17·3	− 3·9	+ 6·0	+14·2
+ 4·5	− 1·4	+11·6	+21·5	+29·8	−11·9	−17·8	− 4·8	+ 5·1	+13·4
+21·8	+17·7	+28·5	+36·7	+42·3	+ 5·4	+ 1·3	+12·1	+20·3	+25·9
+ 2·8	− 2·0	+12·8	+23·5	+32·0	−13·6	−18·4	− 3·6	+ 7·1	+15·6
5·6	3·9	12·8	23·5	32·0	13·9	18·5	4·6	7·1	15·6
30·5	27·7	23·6	20·4	18·0	30·4	28·7	23·6	20·4	18·0

TABLE 8.—*Gravity Anomalies in East*

No.	Stations	Height	Latitude	Longitude	g (metre factor 0·0817)	HEL $g-\gamma_A$	$g-\gamma_B$	Modified $g-\gamma_B$†
		feet	° ′ ″	° ′ ″	*gals*	*mgals*	*mgals*	*mgals*
31	Ludhiāna S.B.M.	805	30 54 52	75 50 25	979·2793	−38·7	−65·8	−63·4
32	Ludhiāna Pend. Stn.	835	55 25	51 09	·2768	−39·1	−67·2	−63·8
33	Pandori P.W.D.R.H.	788	49 56	38 12	·2783	−34·6	−61·1	−58·8
34	Jagraon P.W.D.R.H.	759	48 39	27 51	·2918	−22·2	−47·7	−45·6
35	Raikot P.S.	775*	38 51	35 40	·2738	−25·8	−51·9	−49·6
36	Dehlon P.O.	825*	44 40	51 00	·2671	−35·5	−63·2	−60·7
37	Malerkotla R.H.	802*	31 18	53 20	·2472	−40·0	−67·0	−64·5
38	Boundary between P.E.P.S.U. and Ludhiāna District ..	822*	40 05	51 25	·2605	−36·3	−63·9	−61·4
39	Dhūri Railway Crossing ..	787*	22 25	51 49	·2413	−35·6	−62·1	−59·7
40	Sangrūr Railway Crossing ..	771*	15 42	50 10	·2387	−30·9	−56·8	−54·6
41	Sangrūr D.B. (Pend. Stn.) ..	772*	14 37	50 06	·2375	−30·6	−56·6	−54·3
42	Patiāla-Sunām Road Junction ..	765*	09 27	54 05	·2355	−26·4	−52·1	−49·8
43	Gharachon ..	778*	30 13 00	75 57 35	979·2330	−32·3	−58·5	−56·2
	Mean with regard to sign					−32·9	−59·5	−57·1
	Mean without regard to sign ..					32·9	59·5	57·1
	Range					17·8	19·5	18·9

* Approximate heights.
† Modified $g-\gamma_B = g-\gamma_A$—attraction of topography up to zone O.

Punjab and P.E.P.S.U. (Sheet 44 N)

MERT'S FORMULA					INTERNATIONAL FORMULA				
Hayford's compen-sation 113·7 km.	HEISKANEN'S REGIONAL COMPENSATION				Hayford's compen-sation 113·7 km.	HEISKANEN'S REGIONAL COMPENSATION			
	40 km.	60 km.	80 km.	100 km.		40 km.	60 km.	80 km.	100 km.
mgals	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*	*mgals*
+ 8·3	+ 1·7	+16·1	+27·7	+36·7	− 8·1	−14·7	− 0·3	+11·3	+20·3
+ 8·1	+ 1·6	+16·0	+27·7	+36·6	− 8·3	−14·8	− 0·4	+11·3	+20·2
+ 5·6	− 1·2	+12·0	+22·8	+31·4	−10·8	−17·6	− 4·4	+ 6·4	+15·0
+15·6	+ 8·8	+20·8	+31·1	+39·5	− 0·8	− 7·6	+ 4·4	+14·7	+23·1
+11·2	+ 4·4	+16·4	+26·3	+34·6	− 5·2	−12·0	0·0	+ 9·9	+18·2
+ 6·5	+ 0·5	+14·1	+24·8	+33·7	− 9·9	−15·9	− 2·3	+ 8·4	+17·3
− 1·0	− 7·0	+ 5·7	+15·8	+24·0	−17·4	−23·4	−10·7	− 0·6	+ 7·6
+ 5·1	− 0·8	+12·4	+23·2	+31·7	−11·3	−17·2	− 4·0	+ 6·8	+15·3
+ 0·2	− 6·0	+ 5·4	+14·9	+23·0	−16·2	−22·4	−11·0	− 1·5	+ 6·6
+ 2·2	− 3·4	+ 7·7	+17·0	+24·4	−14·2	−19·8	− 8·7	+ 0·6	+ 8·0
+ 2·4	− 3·2	+ 7·7	+16·8	+24·2	−14·0	−19·6	− 8·7	+ 0·4	+ 7·8
+ 6·9	+ 1·1	+12·1	+21·3	+28·8	− 9·5	−15·3	− 4·3	+ 4·9	+12·4
+ 3·6	− 3·4	+ 7·8	+17·5	+25·1	−12·8	−19·8	− 8·6	+ 1·1	+ 8·7
+ 5·7	− 0·5	+11·9	+22·1	+30·3	−10·7	−16·9	− 4·5	+ 5·7	+13·9
5·9	3·3	11·9	22·1	30·3	10·7	16·9	5·2	6·0	13·9
16·6	15·8	15·4	16·2	16·5	16·6	15·8	15·4	16·2	16·5

CHAPTER VII

COMPUTATIONS, PUBLICATIONS AND TRAINING

BY B. L. GULATEE, M.A. (CANTAB.), F.R.I.C.S., M.I.S. (INDIA)

59. **Adjustment of Topographical Triangulation in India.**—The personnel of the Computing Office remained busy with the reduction of the field work and much progress could not be made with the adjustment and compilation for the press of data of topographical triangulation in India, a start on which was made in 1948–49 (see Technical Report 1948–49, Part III, para 84). Although the work has been very slow, all data falling in sheets 54 B and 47 E has been assembled and is now being scrutinized.

60. **Triangulation Data in Irāq and Irān.**—The compilation and publication of data of triangulation in Irāq and Irān carried out by the Indian Military survey units during World Wars I and II, the Irāq Survey Department and Anglo-Iranian Oil Company was continued during the period under report. Out of an estimated total of about 80 pamphlets, 28 have so far been published. Each pamphlet generally contains data covering an area of one degree of latitude by one degree of longitude, but where data is sparse a larger area has been included in one pamphlet. An account of the triangulation is given in Technical Report 1947, Part III, paras 46 to 49 and in the Preface to each pamphlet, which also gives details of the adjustment of the various series of triangulation.

61. **Computations.**—The results of the following field observations were computed :—

(i) Observations of geodetic triangulation for the Bengal Boundary Survey.

(ii) Observations of the geodetic triangulation and base measurement in the Andamans.

(iii) Traverse of the Car Nicobar Island.

(iv) Levelling of high precision from Bombay to Kārwār and from Kolhāpur to Raichūr via Wadi.

(v) Levelling of precision in the Andamans.

(vi) Secondary levelling for the Bhakra Dam Project (Jullundur area) and in Rājasthān.

(vii) Tertiary levelling in Car Nicobar Island.

A narrative account together with a discussion of results of the geodetic triangulation is given in Chapter I and that of levelling in Chapter III.

Deflections at 11 stations and gravity anomalies at 47 new stations have been computed and the charts of the Geoid (Chapter V) and Gravity Anomalies (Chapter VI) have been revised.

62. **Inspection of G.T. Stations.**—The stations of geodetic triangulation in India (excluding Burma and Pākistān) which number about 3,000 are placed in the custody of district officials for preservation and maintenance. These stations are generally marked by a circle and dot cut on rock or a loose stone. In hilly country the mark is surmounted by a low pillar of stones or bricks, surrounded by a large platform of loose stones and covered by a cairn. In the past, in flat country, towers were built over the marks to ensure intervisibility. These comprised of an inner circular masonry pillar built over the mark, with a number of other mark-stones inserted in it at different heights. This pillar was surrounded by a huge hollow tower built to the same height as the pillar but separated from it by an annular space which was filled with rubble or earth. A staircase enabled one to get to the top of the tower for observations.

Most of the geodetic triangulation stations are now nearly a century old. The hill stations have remained in good condition but the tower stations, which were built at a very high cost have either totally crumbled down and are just a mound of earth or are in a condition unfit for use.

Annual reports on the condition of these stations are made to the Director, Geodetic and Training Circle by the district officers together with an estimate of cost of any repairs considered necessary. It has of late been found that these reports by local authorities and the repairs carried out have generally not been satisfactory. It has thus become necessary that these stations be reported upon by Survey officers whenever it is possible to do so. The original intention was to organize a field detachment to visit all old stations according to a systematic programme and to replace the structures of those that had become unidentifiable by monuments of a modern design and refix their positions with geodetic accuracy. Due to financial stringency it has not been possible to give effect to this scheme but action has been initiated to obtain accurate and detailed reports on the condition of all G.T. stations visited by Survey units during the course of their work. Hitherto the reports made were generally vague and did not serve the object in view. A new form O.139 (Tech.) has been designed and issued to all Regional Directors for this purpose. A specimen of the form is given opposite.

In pursuance of this scheme detailed reports have been received on the condition of a number of G.T. stations. These stations are given in Table 1 at end.

O. 139 (Tech.) SURVEY

Report on condition and repair of G.T. and protected (G.T. minor and pakka Topo.)

1. Date of Inspection .. .. ..
2. Name and designation of the inspecting officer ..
3. Name of Station and 1-inch Sheet No. .. ..
4. Latitude and Longitude of the station .. ..
5. Local name of the station .. .. ..
6. Names of the nearest Village, Tehsil and District ..
7. Name of the nearest Post Office, R.S. and Police Station .. ..
8. Details of the structure on the day of inspection :—
   (i) Is it a solid pillar or a hollow tower ? ..
   (ii) Is it circular or rectangular and of what dimensions ? .. .. ..
   (iii) Is it of *pakka* masonry or *kachcha* bricks or mud ?
   (iv) What is the height of the tower or pillar ? State if it is intact or partially fallen down or reduced to a mound .. ..
   (v) Is it surrounded by a masonry ring, if so, how thick ?
   (vi) Is there a platform around it ? If so, give its structure and dimensions .. ..
   (vii) What is the structure and dimensions of the rectangular protecting pillar if there is one ?
   (viii) How many mark-stones had the original tower or pillar ? .. ..
   Which of these mark-stones are now identifiable ?
   (ix) Which of the mark-stones can be used for observations ? Is the lowermost mark-stone accessible ? If not, how can it be made accessible ? ..
   (x) Give any other remarks that will help in giving a clear picture of the structure of the station existing on the date of inspection, and whether the site of the original station is recognizable without any doubt or not .. .. ..
9. Bearing and distance of auxiliary marks if any ..
10. Station tree (i) Its height .. .. ..
    (ii) Its bearing and distance at station
11. Amount of jungle clearing if necessary .. ..
12. Types of conveyance available and rates.. ..
13. Availability of local labour and rates .. ..
14. Name and address of the local official under whose charge the station is .. .. ..
15. Has the station been kept in good repair by the said official ? .. ..
16. Has the attention of this local official been drawn to any defects in the system of repairs ? If so, to what defects ? .. .. ..
17. Record discrepancies in the original description
18. What protective measures have you taken before leaving the station ? (Give details of repairs carried out, if any).
    The usual protective measures are :—
    (i) To remove vegetation from towers and pillars and from their immediate neighbourhood, especially trees growing within 30 feet of the station, if they have deep or spreading roots, likely to damage the structure.
    ii) To stop all cracks in masonry, block all passages, windows, etc., which might admit rain or animals.
    (iii) If the masonry has broken, to heap it up into a pil to protect the pillar or mark-stone.
    (iv) To drain away any water collected near the base and fill in hollow ground ; the fact that water had been found at the base should be mentioned in 8(x) above.

Note :—(*a*) It is more important to protect the mark-stone, than to rebuild the undertaken. Under no circumstances should a new mark be cut at
(*b*) It is essential that the actual site of the station be preserved even if no original site and plastering it over by mud and lime at a small cost.

OF INDIA

stations by No...................Party. Season..................

tower or pillar: repairs liable to disturb the position of the mark-stone should not be the site of the old G.T. and protected (G.T. minor and *pakka* Topo.) stations. mark-stone exists. This can be done by raising a pile of earth and stones over the

Signature of the Inspecting Officer.

63. **Institution of Surveyors (India).**—In April 1949, the Surveyor General of India proposed to the Government of India, the setting up of an Institution of Land Surveyors (India), on the lines of the Royal Institution of Chartered Surveyors (Land Survey Division) in U.K. The proposal was placed before the Advisory Committee, for co-ordinating Scientific work at a meeting held on 17th July 1949, at which a sub-committee consisting of the following was formed to examine the proposal :—

1. Brigadier G. F. Heaney, C.B.E., Surveyor General of India, Convenor.
2. Major General H. Williams, C.B.E., Engineer-in-Chief.
3. Dr. D. S. Kothari, Scientific Adviser to the Ministry of Defence.
4. Mr. B. L. Gulatee, M.A. (Cantab.), President, Geodetic and Research Branch, Survey of India.
5. Mr. N. G. Dewan, I.S.E., Superintending Engineer, Delhi Province.
6. Mr. T. Gonsalves, Under Secretary to the Government of India, Department of Scientific Research.

This sub-committee unanimously agreed on the desirability of the formation of an Institution of Surveyors (India) and to include in it two divisions, viz., Division I (Land Surveying) and Division II (Building and Quantity Surveying). It was also decided to prepare a draft of the Memorandum of Association and Rules of the Institution and also draw up Rules and Syllabus for the various Professional examinations and to submit these with recommendation to the Government of India to accord their approval to the scheme.

In India, there is no institution except the Survey of India Department which has the knowledge, experience and the necessary equipment to give a comprehensive training in all branches of land survey work (Division I). Prior to the formation of the Institution of Surveyors it was concerned only with the imparting of practical training to its officers, the theoretical aspects of the survey work being generally neglected due to the lack of proper instructors and want of a well planned syllabus. The whole programme of training has been redesigned and a suitable syllabus devised to enable the trainee officers to pass the professional examinations of the Institution of Surveyors (India).

The first departmental examination equivalent to the Intermediate Examination of the Institution of Surveyors was held at Dehra Dūn from 25th to 30th September 1950. Seven Class I Officers sat for the examination.

Future examinations will be held under the auspices of the Institution of Surveyors simultaneously at Dehra Dūn, Bombay and Calcutta.

A few officers from Burma, Afghānistān, Sikkim and Nepāl have also been deputed by their governments from time to time for training and have been attached to the Training Party. In addition, the various state governments have sent officers of the Land Records and Settlement Surveys for general training with a view to getting a good background to appreciate the problems which arise in their day to day work and to ensure a proper liaison between these state departments and the Survey of India.

64. **Publications Issued.**—The following publications were seen through the press :—

1. Technical Report 1950, Part III—Geodetic Work.
2. Grid data triangulation pamphlets for Irāq and Irān, five in number.
3. Survey Star Almanac, 1951.
4. Departmental Paper No. 10, "Hunter Short Base".
5. Technical Paper No. 4 "Mount Everest—Its name and height".
6. Accounts Pamphlet, Chapters I and II.
7. Memorandum of Association and Rules for the Institution of Surveyors (India).
8. Rules and Syllabus for the Professional Examinations of the Institution of Surveyors (India).
9. Question Papers set at the Intermediate Examination of the Institution of Surveyors (India), 1950.

TABLE 1.—*Report on the condition of G.T. Stations*

Name of station		Sheet No.	Name of Inspecting Officer	Date of Inspection	Brief report
NORTHERN CIRCLE					
Bhada	H.S.	44 D	N. B. Chaudhry and Ishar Singh	5th Dec. 1950	Good.
Jodasar	H.S.	44 D	H. K. Chopra	10th March 1951	Middle mark-stone expected intact.
Karamala	H.S.	44 D	N. B. Chaudhry and Ishar Singh	31st Dec. 1950	Good.
Khirsar	H.S.	44 D	H. K. Chopra	15th March 1951	Middle mark-stone intact.
Mankasar	H.S.	44 D	H. K. Chopra	27th Jan. 1951	Middle mark-stone intact.
Modia	H.S.	44 D	N. B. Chaudhry	16th Feb. 1951	Good.
Mugrala	H.S.	44 D	N. B. Chaudhry	10th March 1951	Good.
Ronesar	H.S.	44 D	H. K. Chopra	29th Jan. 1951	Middle mark-stone intact.
Uperthal	H.S.	44 D	H. K. Chopra	24th Jan. 1951	Middle mark-stone intact.
Johārki	T.S.	44 G	N. B. Chaudhry and D. D. Mehta	19th Nov. 1950	Upper mark-stone missing.
Kāla-Thal	S.	44 K	R. S. Chhabra	11th April 1951	Lower mark-stone intact.
Khairwāla	S.	44 K	R. S. Chhabra	10th April 1951	Lower mark-stone intact.
Hiu	S.	44 M	Mohan Ram	March 1951	Good.
Kalla	T.S.	44 M	Dayanand	19th March 1951	Good.
Sangatpur	T.S.	44 M	Dayanand	18th March 1951	Good.
Shāmpura	S.	44 P	Dayanand	10th Jan. 1951	Middle mark-stone intact.
Bārādevi	H.S.	53 A	Ratna Singh	15th Oct. 1950	Upper mark-stone displaced downwards.
Medwāni	H.S.	53 A	Mohan Ram	Nov. 1950	No mark-stone found.
Rahūn	S.	53 A	Mohan Ram	Nov. 1950	Expected good, station not climbed.
Gādowāl	T.S.	53 B	R. M. Raj	18th Dec. 1951	Good.
Kado	T.S.	53 B	R. M. Raj	23rd Dec. 1951	Good.
Nāda	H.S.	53 B	Dial Singh	1949-50	In collapsing condition.
Chitān (Chautan)	S.	53 F	Dial Singh	20th Jan. 1950	Good.
Rāmpur	H.S.	53 F	Dial Singh	18th Jan. 1951	Good.

(Continued)

TABLE 1.—*Report on the condition of G.T. Stations*—(contd.)

Name of station		Sheet No.	Name of Inspecting Officer	Date of Inspection	Brief report
NORTHERN CIRCLE—(*concld.*)					
Banog	H.S.	53 J	V. P. Sharma	1950-51	Good.
Bhitāri	H.S.	54 K	Raja Ram	12th Feb. 1951	Good.
Anjania Khurd	H.S.	55 B	S. D. P. Jakhmola	28th Jan. 1950	Good.
Baodiya	H.S.	55 B	S. D. P. Jakhmola	19th Nov. 1950	Good.
Mathni	H.S.	55 B	Suresh Prasad	21st Dec. 1950	Good.
Rewapur	H.S.	55 B	S. D. P. Jakhmola	10th Oct. 1950	Good.
Goulan Khodra	H.S.	55 C	S. D. P. Jakhmola	22nd Nov. 1950	Good.
Sahejla	H.S.	55 C	S. D. P. Jakhmola	21st Nov. 1950	Good.
Jājmau	T.S.	63 B	Lachhman Dass	4th May 1951	Lower mark-stone usable.
Bagāla	H.S.	63 G	T. C. Jyoti	9th Dec. 1950	Good, mark-stone expected under the pillar.
Singraur	T.S.	63 G	T. C. Jyoti	11th Dec. 1950	Lower mark-stone usable.
Barjana	H.S.	64 E	S. D. Bhatt	16th Oct. 1950	Good.
Bhalua	H.S.	64 E	S. D. Bhatt	28th Oct. 1950	Good.
EASTERN CIRCLE					
Rāmnagar	T.S.	72 A	K. L. Chakarvarty	29th Dec. 1950	Lower mark-stone usable.
Biarwa	T.S.	72 B	K. L. Chakarvarty	3rd Jan. 1951	Lower mark-stone usable.
Naonangarhi	S.	72 B	K. L. Chakarvarty	1st Jan. 1951	Destroyed.
Patjirwa	T.S.	72 B	Sukhwant Rai	26th Dec. 1950	Lower mark-stone intact.
Rūpdi	T.S.	72 B	Sukhwant Rai	15th April 1951	Good.
Sathwaria	T.S.	72 B	K. L. Chakarvarty	1st Jan. 1951	Lower mark-stone usable.
Bandarjūla	T.S.	72 N	K. L. Puri	1949-50	Pillar not traceable.
Banghora	T.S.	72 N	B. S. Rattan	1949-50	Only a mound of earth found.
Dipnagar	T.S.	72 N	P. S. Ojha	1949-50	Good.

(*Continued*)

TABLE 1.—*Report on the condition of G.T. Stations*—(contd.)

Name of station		Sheet No.	Name of Inspecting Officer	Date of Inspection	Brief report
EASTERN CIRCLE—(*concld.*)					
Ghiba	T.S.	72 N	B. S. Rattan	1949–50	Station fully covered by a gigantic tree.
Lachmipur	T.S.	72 N	B. S. Rattan	1949–50	Destroyed.
Mānikpur	T.S.	72 N	B. S. Rattan	1949–50	Destroyed.
Musaldanga	T.S.	72 N	B. S. Rattan	1949–50	Destroyed.
Nirpur	T.S.	72 N	B. S. Rattan	1949–50	Destroyed.
Dumdāngi	T.S.	78 B	K. L. Puri	1949–50	Upper mark-stone missing, pillar not well identified.
Kharkhari	T.S.	78 B	B. S. Rattan	1949–50	A mound of earth with no pillar or mark-stone.
Sonakhoda	T.S.	78 B	K. L. Puri	1949–50	Upper mark-stone missing, pillar cracked.
Thakurganj	T.S.	78 B	K. L. Puri	1949–50	Pillar buried in earth.
Chatra	T.S.	78 D	L. R. Howard	24th Nov. 1950	Destroyed.
Debipur	T.S.	78 D	L. R. Howard	1st Dec. 1950	Destroyed.
Imāmnagar	T.S.	78 D	L. R. Howard	6th Nov. 1950	Tower fallen, ground level mark-stone expected intact.
Jitpur	T.S.	78 D	L. R. Howard	30th Oct. 1950	Tower tilted, ground level mark-stone usable.
Murcha	T.S.	78 D	L. R. Howard	28th Nov. 1950	Destroyed.
Sisa	T.S.	79 A	L. R. Howard	2nd Nov. 1950	Tower fallen, ground level mark-stone expected intact.
SOUTHERN CIRCLE					
Alamvādi	H.S.	46 G	C. Sivaraman	8th Jan. 1951	No mark-stone found.
Kesarva	H.S.	46 G	C. Sivaraman	9th May 1951	Lower mark-stone usable.
Sāgbāra	H.S.	46 G	C. Sivaraman	20th May 1951	Good.
Pilva	H.S.	46 H	K. G. Ramanna	15th April 1951	No mark-stone found.
Trombāy	H.S.	47 A	Y. D. Hegde	1950	Mark-stone intact, pillar cracked.
Bombay Longitude Station	..	47 B	Y. D. Hegde	1949–50	Good.

(*Continued*)

TABLE 1.—*Report on the condition of G.T. Stations*—(contd.)

Name of station	Sheet No.	Name of Inspecting Officer	Date of Inspection	Brief report
SOUTHERN CIRCLE—(*contd.*)				
Colāba Observatory, Bombay..	47 B	Y. D. Hegde	1949–50	Good.
Dighi H.S.	47 F	Gokal Chand	1949–50	Good.
Shelārvādi H.S.	47 F	Gokal Chand	6th Jan. 1950	Good.
Adhūr H.S.	47 G	S. Krishnamurthy	6th April 1951	Lower mark-stone usable.
Kumbhārli H.S.	47 G	S. Krishnamurthy	26th Feb. 1951	Bad. Only a + mark identified.
Mahābaleshvar H.S.	47 G	J. E. David	8th May 1951	Lower mark-stone probably usable.
Mirya H.S.	47 G	S. Krishnamurthy	13th March 1951	Original (lower) mark-stone usable.
Ghirya H.S.	47 H	P. Ramamoorthy	6th Feb. 1951	Good.
Valvan H.S.	47 H	P. Ramamoorthy	21st April 1951	Good.
Karigudd H.S.	47 L	Y. D. Hegde	1949–50	Good.
Kolanhatti H.S.	48 I	P. G. Balachandran	1949–50	Good.
Yalūr H.S.	48 I	P. G. Balachandran	1949–50	Good.
Hyderābād Naubatpahār H.S.	56 K	R. S. Ramamoorthi	13th March 1951	Destroyed.
Lachhmanpur H.S.	56 K	R. S. Ramamoorthi	17th March 1951	Lower mark-stone intact.
Secunderābād H.S.	56 K	R. S. Ramamoorthi	12th March 1951	Good.
Bangalore Base-line SW. End S.	57 G	Lorind Chand	28th Nov. 1950	Good.
Halasūrbetta H.S.	57 G	C. M. Azimuddin	1949–50	Good.
Mandūr H.S.	57 G	C. M. Azimuddin	1949–50	Lower mark-stone usable.
Bannergatta H.S.	57 H	C. M. Azimuddin	1949–50	Good.
Hōsūr H.S.	57 H	C. M. Azimuddin	1949–50	Good.
Turukungutta H.S.	57 H	S. Krishnamurthy	15th July 1950	Good.
Coimbatore S.	58 A	S. Ramakrishnan	17th Nov. 1950	Destroyed.
Ettimalai No. 1 H.S.	58 B	S. Ramakrishnan	27th Nov. 1950	Good.
Chēnjeri H.S.	58 F	S. Ramakrishnan	23rd March 1951	Destroyed.

(*Continued*)

TABLE 1.—*Report on the condition of G.T. Stations*—(concld.)

Name of station	Sheet No.	Name of Inspecting Officer	Date of Inspection	Brief report
SOUTHERN CIRCLE—(*concld.*)				
Edayārpālaiyam S.	58 F	S. Ramakrishnan	7th Dec. 1950	Good.
Kinattukkadavu H.S.	58 F	S. Ramakrishnan	26th March 1951	Good.
Cape Comorin Base-line N. End T.S.	58 H	K. B. K. Menon	28th Oct. 1950	Good.
Cape Comorin Base-line S. End T.S.	58 H	K. B. K. Menon	13th May 1951	Good.
Manpōttai H.S.	58 H	K. B. K. Menon	18th April 1951	Good.
Pĕddarangapuram S.	58 H	K. B. K. Menon	1st Nov. 1950	Good.
Annavasal H.S.	58 J	K. B. K. Menon	1st June 1950	Good.
Paiyal S.	58 J	K. B. K. Menon	1st June 1950	Good.
Bezwāda H.S.	65 D	A. Ramachandran	29th Nov. 1950	Platform destroyed, mark on rock usable.
Yerragattu H.S.	65 D	A Ramachandran	5th Dec. 1950	Good.
Yārāda H.S.	65 O	A. Karunakaran	22nd Nov. 1950	No mark-stone identified, pillar intact.
Māngād H.S.	66 C	S. Ramakrishnan	1949-50	Good.
St. Thomas's Mount Trestle S.	66 C	S. Ramakrishnan	1949-50	Good.
Nanmangalam H.S.	66 D	S. Ramakrishnan	1949-50	Good, pillar slightly cracked.

LIST OF IMPORTANT GEODETIC PUBLICATIONS AND CONTRIBUTIONS BY OFFICERS OF THE SURVEY OF INDIA

(A) Publications.

No.	*Name of Book*	*Details*
1.	G.T.S. Vol. II	History and General Description of the Reduction of the Principal Triangulation. Dehra Dūn, 1879. *Price Rs. 10-8.*
2.	G.T.S. Vol. IX	Telegraphic Longitudes. During the years 1875–77 and 1880–81. Dehra Dūn, 1883. *Price Rs. 10-8.*
3.	G.T.S. Vol. X	Telegraphic Longitudes. During the years 1881–82, 1882–83 and 1883–84. Dehra Dūn, 1887. *Price Rs. 10-8.*
4.	G.T.S. Vol. XI	Astronomical Latitudes. During the period 1805–1885. Dehra Dūn, 1890. *Price Rs. 10-8.*
5.	G.T.S. Vol. XV	Telegraphic Longitudes. From 1885 to 1892 and the Revised Results of Vols. IX and X: also the Simultaneous Reduction and final Results of the whole Operations. Dehra Dūn, 1893. *Price Rs. 10-8.*
6.	G.T.S. Vol. XVI	Tidal Observations. From 1873 to 1892 and the Methods of Reduction. Dehra Dūn, 1901. *Price Rs. 10-8.*
7.	G.T.S. Vol. XVII	Telegraphic Longitudes. During the years 1894–95–96. The Indo-European Arcs from Karāchi to Greenwich. Dehra Dūn, 1901. *Price Rs. 10-8.*
8.	G.T.S. Vol. XVIII	Astronomical Latitudes. From 1885 to 1905 and the deduced values of Plumb-line Deflections. Dehra Dūn, 1906. *Price Rs. 10-8.*
9.	G.T.S. Vol. XIX	Levelling of Precision in India. From 1858 to 1909. Dehra Dūn, 1910. *Price Rs. 10-8.*
10.	Records of the Survey of India, Vol. XIX	1901–20. The Magnetic Survey, by Lt.-Colonel R. H. Thomas, D.S.O., R.E. and E. C. J. Bond, V.D. Dehra Dūn, 1925. *Price Rs. 4.*

No.	*Name of Book*	*Details*
11.	Geodetic Report Vol. I	1922–25. Computations and Research. Tidal work. Time and Magnetic observations. Latitude and Pendulum observations in Bihār, Assam and Kashmīr. Levelling. Lecture on "The height of Mount Everest and other Peaks". Dehra Dūn, 1928. *Price Rs. 6.*
12.	Geodetic Report Vol. II	1925–26. Computations and Research. Tidal work. Time and Magnetic observations. Preparations for the International Longitude Project. Triangulation. Levelling. Investigation of the behaviour of tree bench-marks in India. Dehra Dūn, 1928. *Price Rs. 3.*
13.	Geodetic Report Vol. III	1926–27. The International Longitude Project. Computations and Publication of data. Observatories. Tides. Gravity and Deviation of the Vertical. Triangulation. Levelling. Research and Technical Notes regarding Personal Equation Apparatus and the height of Mount Everest. Dehra Dūn, 1929. *Price Rs. 3.*
14.	Geodetic Report Vol. IV	1927–28. Computations and Publication of data. Observatories. Tides. Gravity and Deviation of the Vertical. Triangulation. Levelling. Dehra Dūn, 1929. *Price Rs. 3.*
15.	Geodetic Report Vol. V	1928–29. Computations and Publication of data. Observatories. Tides. Gravity and Deviation of the Vertical. Triangulation. Levelling. Research and Technical Notes. Dehra Dūn, 1930. *Price Rs. 3.*
16.	Geodetic Report Vol. VI	1929–30. Computations and Publication of data. Observatories. Tides. Gravity. Triangulation. Levelling. Research and Technical Notes. Dehra Dūn, 1931. *Price Rs. 3.*
		Supplement. Indian Deflection and Gravity stations. Dehra Dūn, 1931. *Price Rs. 1-8.*
17.	Geodetic Report Vol. VII	1930–31. Computations and Publication of data. Observatories. Tides. Deviation of the Vertical. Gravity. Triangulation and Base Measurement. Levelling. The Magnetic Survey. Dehra Dūn, 1932. *Price Rs. 3.*

No.	*Name of Book*	*Details*
18.	Geodetic Report Vol. VIII	1931–32. Computations and Publication of data. Observatories. Tides. Gravity. Triangulation. Levelling. Research and Technical Notes. Dehra Dūn, 1933. *Price Rs. 3.*
19.	Geodetic Report 1933	Triangulation and Base Measurement. Levelling. Deviation of the Vertical. Computations and Publication of data. Observatories. Tides. Research and Technical Notes. Dehra Dūn, 1934. *Price Rs. 3.*
20.	Geodetic Report 1934	Triangulation and Base Measurement. Levelling. Gravity. Deviation of the Vertical. Computing Office and Tidal Section. The International Longitude Project. Observatories. Research and Technical Notes. Dehra Dūn, 1935. *Price Rs. 3.*
21.	Geodetic Report 1935	Triangulation. Levelling. Deviation of the Vertical. Gravity. Geophysical Survey in Bihār. Computing Office and Tidal Section. Observatories. Research and Technical Notes. Dehra Dūn, 1936. *Price Rs. 3.*
22.	Geodetic Report 1936	Triangulation. Levelling. Deviation of the Vertical. Gravity. Computing Office and Tidal Section. Observatories. Subsoil Water Levels. Levelling in Bengal and Bihār. Dehra Dūn, 1937. *Price Rs. 3.*
23.	Geodetic Report 1937	Triangulation. Levelling. Gravity. Magnetic Survey in Bihār. Computing Office and Tidal Section. Observatories. Dehra Dūn, 1938. *Price Rs. 3.*
24.	Supplement to Geodetic Report 1937	Isostatic reductions of Indian Gravity Stations. Dehra Dūn, 1939. *Price Rs. 2-8.*
25.	Geodetic Report 1938	Triangulation and Levelling. Deviation of the Vertical. Gravity. Computing Office and Tidal Section. Observatories. Dehra Dūn, 1939. *Price Rs. 3.*
26.	Geodetic Report 1939	Levelling. Gravity. Computing Office and Tidal Section. Observatories. Research and Technical Notes. Dehra Dūn, 1940. *Price Rs. 3.*
27.	Geodetic Report 1940	Levelling. Deviation of the Vertical Gravity. Computing Office and Observatories. Dehra Dūn, 1945. *Price Rs. 2.*

No.	*Name of Book*	*Details*
28.	Technical Report 1947, Part III, Geodetic Work	Triangulation in the Neighbouring Countries of India. Levelling. Gravity. Deviation of the Vertical. Computations and Publications. Tides. Observatories. Dehra Dūn, 1948. *Price Rs. 4.*
29.	Technical Report 1948–49, Part III, Geodetic Work	Triangulation. Levelling. Gravity. Deviation of the Vertical. Tides. Observatories. Computations and Publications. Research and Technical Notes. Dehra Dūn, 1950. *Price Rs. 4.*
30.	Technical Report, 1950, Part III, Geodetic Work	Triangulation and Base Measurement. Levelling. Gravity. Deviation of the Vertical. Tides. Observatories. Computations and Publications. Dehra Dūn, 1951. *Price Rs. 4.*
31.	Technical Report 1951, Part III, Geodetic Work	Triangulation and Base Measurement. Observatories. Levelling. Tides. Deviation of the Vertical. Gravity. Computations, Publications and Traninig. Dehra Dūn. 1952. *Price Rs. 4.*
32.	Report on the Geodetic Work for 1924–27	Report on the Geodetic Work of the Survey of India for the period 1924–27—Presented at the third general meeting of the Section of Geodesy, Prague, Dehra Dūn, 1927. *Price Re. 1.*
33.	Report on the Geodetic Work for 1927–30	Report on the Geodetic Work of the Survey of India for the period 1927–30—Presented at the fourth general meeting of the Section of Geodesy, Stockholm, Dehra Dūn, 1930. *Price Rs. 1-12.*
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No.	*Name of Book*	*Details*
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45.	War Research Series Pamphlet No. 6	Magnetic Anomalies (India and Burma), 1944. *Price Re. 1.*
46.	War Research Series Pamphlet No. 9	**The Trans-Persia Triangulation 1941–44.** (linking Irāq and India), by J. de Graaff Hunter, C.I.E., SC.D., F.R.S. and B. L. Gulatee, M.A. (Cantab.), with an Appendix "The Persia–India Connection", by Maj. P. A. Thomas, I.E., Dehra Dūn. *Price Rs. 2.*
47.	Memoirs of The Survey Research Institute Vol. 1, No. 1	Geophysical Prospecting for Manganese near Rāmtek, C.P., by B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1947. *Price Rs. 3.*
48.	Technical Paper No. 2	Value of Gravity at Dehra Dūn, by B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1948.

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49.	Technical Paper No. 3	Levelling in India, Past and Future, by B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1949.
50.	Technical Paper No. 4	Mount Everest, its Name and Height, by B. L. Gulatee, M.A. (Cantab.). Dehra Dūn, 1950.
51.	Technical Paper No. 5	Geodetic and Geophysical aspects of the earthquakes in Assam, by B. L. Gulatee, M.A. (Cantab.), F.R.I.C.S., M.I.S. (IND.). Dehra Dūn, 1951.
52.	.. ..	Question Papers set at the Intermediate Examination of the Institution of Surveyors (India) in 1950. Dehra Dūn, 1950. *Price As. -/8/-*
53.	.. ..	Question Papers set at the Intermediate Examination, Sub-Division I (Land Surveying) of the Institution of Surveyors (India) in 1951. *Price As. -/12/-.*
54.	.. ..	Question Papers set at the Final Examination, Sub-Division I (Land Surveying) of the Institution of Surveyors (India) in 1951. *Price As. -/6/-.*

(B) Articles on Geodetic Subjects.

1. The Indian Geoid and Gravity Anomalies, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. and Capt. G. Bomford, R.E. (Bulletin Géodésique, No. 29, Jan.–March 1931, pp. 20, 21, Paris).
2. Construction of the Geoid, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. and Capt. G. Bomford, R.E. (Bulletin Géodésique, No. 29, Jan.–March 1931, pp. 22–26, Paris).
3. *†The Hypothesis of Isostasy, by J. de Graaff Hunter, M.A., SC.D., F. INST. P. (The Observatory, Dec. 1931 and Geophysical Supplement to Monthly Notices of the Royal Astronomical Society, January 1932).
4. ‡Stokes's Formula in Geodesy, by B. L. Gulatee, M.A. (Cantab.), (Nature, 20th Feb. 1932).
5. *" Crustal Warpings " discussing the gravity work of the Survey of India, by Maj. E. A. Glennie, D.S.O., R.E. (The Observatory January and April 1933).

* Obtainable from Messrs. Taylor and Francis, Red Lion Court, Fleet Street, London, W.C.

† Obtainable from the Royal Astronomical Society, Burlington House, London, W. 1.

‡ Obtainable from the office of Nature, St. Martin's Street, London, W.C. 2.

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6.	*Figure of the Earth, by B. L. Gulatee, M.A. (Cantab.), (Gerlands Beiträge, Bd. 38, H. 3/4, S.426, 1933).
7.	†Deflection of the Plumb-Line, by B. L. Gulatee, M.A. (Cantab.), (Hydrographic Review, Vol. X, No. 2, Nov. 1933, pp. 182–189).
8.	*Isostasy in India, by Lt.-Colonel E. A. Glennie, D.S.O., R.E. (Gerlands Beiträge Zur Geophysik, Vol. 43, No. 4, 1935).
9.	‡The Figure of the Earth from Gravity Observations and the Precision Obtainable, by J. de Graaff Hunter, C.I.E., SC.D. (Philosophical Transactions, Royal Society, Series A, Vol. 234, 1935).
10.	§On the Subterranean Mass-Anomalies in India, by B. L. Gulatee, M.A. (Cantab.), (Proceedings of the Academy of Sciences, U.P. India, Vol. 5, Sept. 1935).
11.	*Crustal Warping in the United States, by Lt.-Col. E. A. Glennie, D.S.O., R.E. (Gerlands Beiträge Zur Geophysik, Vol. 46, pp. 193–97, 1936).
12.	*The Boundary Problems of Potential Theory & Geodesy, by B. L. Gulatee, M.A. (Cantab.), (Gerlands Beiträge Zur Geophysik, Vol. 46, pp. 91–98, 1936).
13.	Geophysical Prospecting for Manganese, by B. L. Gulatee, M.A. (Cantab.), (Journal of Scientific and Industrial Research, Vol. III, No. 12, June 1945, pp. 543–54).
14.	Standards of Length, by B. L. Gulatee, M.A. (Cantab.), (Journal of Scientific and Industrial Research, Vol. IV, No. 8, Feb. 1946, pp. 453–59).
15.	Standards of Measurement, by B. L. Gulatee, M.A. (Cantab.), (Journal of Scientific and Industrial Research, Vol. V, No. 3, Sept. 1946, pp. 104–05).
16.	Angular Corrections for the Lambert Orthomorphic Conical Projection, by B. L. Gulatee, M.A. (Cantab.), (Empire Survey Review, Vol. VIII, No. 62, Oct. 1946, pp. 311–14).
17.	Secular Variation of Magnetic Declination in India, by B. L. Gulatee, M.A. (Cantab.), (Science and Culture, Vol. XII, No. 5, Nov. 1946, pp. 215–17).
18.	Future of Geophysics in India, by B.L. Gulatee, M.A. (Cantab.), (Journal of Scientific and Industrial Research, Vol. VI, No. 2, Feb. 1947, pp. 53–59 & 71).

* Obtainable from Akademische Verlagsgesellschaft M.B.H., Leipzig.

† Obtainable from the International Hydrographic Bureau, Monte-Carlo, Monaco.

‡ Obtainable from Messrs. Dulau & Co., 37 Soho Sqaure, London W. or Messrs. Harrison & Sons, St. Martin's Lane, London or The Royal Society at Burlington House, London.

§ Obtainable from the Academy of Sciences, U.P., Allahabad.

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19.	The Hunter Shutter Eye-Piece for Longitude and Azimuth, by J. de Graaff Hunter, C.I.E., SC.D., F.R.S. (Empire Survey Review, Vol. IX, No. 63, Jan. 1947, pp. 20–24).
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22.	Geodetic Work in India—War and Post War, by B. L. Gulatee, M.A. (Cantab.), (Empire Survey Review, Vol. X, No. 77, July 1950, pp. 302–06).
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24.	Tidal Activities of the Survey of India, by B. L. Gulatee, M.A. (Cantab.), [Assoc. Oceanog. Phys. Proces—Verbaux No. 4, pp. 108–10 (1949)].
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